Electrochemical Industry

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Electrochemical Industry

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CONTENTS.

PLATING UPON ALUMINIUM.

Electroplaters have long been largely interested in attempts at coating aluminium with other metals, there being a growing demand especially for gold and silver plating upon certain aluminium objects, such as toilet articles, ornaments, etc. But the difficulties of the problem are well known. While it is easy to get a metallic deposit upon aluminium, it is generally still easier to remove this deposit again by simple pressure. By certain precautions it is possible to get a deposit which will stand the buffing or polishing operations; but even in these cases, the coating is generally loosened afterwards when the article is in daily use, especially when exposed to moisture. The reason why the coating will not stick is that the metal of the coating is not intimately alloyed with the aluminium surface beneath. Zinc is a metal which alloys well with aluminium. Nevertheless, a zinc coating applied to an aluminium surface, under ordinary conditions, will not stick, because the aluminium surface was not aluminium, but coated with that well-known invisible oxide film which gives to aluminium such peculiar properties, and which also causes the difficulties in soldering.

In an article published in this issue Prof. C. F. Burgess and Mr. Carl Hambuechen describe an interesting method of applying to an aluminium surface a coating that sticks. We need not dwell upon the practical importance, as this will be evident to every plater, but we may emphasize that success in this case, as in others, was due to the judicious application of exact principles. Since the oxide film is the cause of all the trouble, it must be removed and an electrolyte must be used which does not allow the film to form again or which will even destroy any traces left. Then the first coating must be made with a metal which alloys well with aluminium; this is zinc. All further plating operations are then the same as plating upon zinc.

WHAT AILED THE DYNAMO?

The story of the sparking dynamo, told in this issue by Mr. David H. Browne, is highly amusing and teaches some instructive lessons. The main moral is that an electrochemical plant should be considered as a complete unit, like an organic body; if one portion of an organic body is out of order, it will affect the whole system, and if there are indications that something is out of order, it is necessary to look for the causes. It is not always the specialist who is the best physician. It is quite inherent in human nature, and in line with our specialization in engineering, that one man is more interested in the chemical part, and another man more in the power-generating part of a plant. This will, of course, always

be so; but if something goes wrong in one part of a plant, the ultimate reason may be found in some other part. In the present case the sparking at the commutator of the dynamo was due to a weak field, and the latter was due to the fact that a number of baths in the electrochemical plant had been disconnected so that the line voltage was lower than that for which the dynamo had been designed.

Mr. Browne is fully justified in emphasizing that there is no use in doctoring symptoms. The repeated turning off of the commutator in the present case had no effect whatever, simply because the commutator itself was not at fault, the sparks being only the symptoms, indicating the fact that the dynamo was operated under conditions for which it was not designed. The lesson taught is that if something is out of order, one should consider the entire plant as a whole, and look for the fundamental cause of the defect. This may be found at quite another place than where the first indications appeared that something was out of order. This may sound commonplace, but is, nevertheless, often overlooked in practice. For instance, in the simplest case of electrolytic action in which a soluble anode is used of the same metal which is to be deposited upon the cathode, it may be found that the cathodic deposition does not proceed properly. To find out the reason, one should consider the whole cell, and should not overlook, for instance, the anode, since the cause of the imperfect cathodic deposition is sometimes due to the fact that the electrolyte is impoverished in the metal ions to be deposited for the reason that the anode has not corroded properly. Doctoring at the cathode would not help matters in this case, since it would be necessary to take care of the anode. It has happened often enough in other cases that the reason of faulty deposition was in the failure of the power supply. For instance, the line voltage may have diminished below the value required for the electrolytic action. By engineers who have been interested in the introduction of the electric precipitation method in the cyanide process in South Africa, it is stated that when the extraction of gold by electrolysis happened to be low, nearly always the unreliability of electric precipitation was cited as the cause, and there the matter very often ended, although it might have been, and sometimes was traced to causes very far removed from its assumed origin, being repeatedly found to be due to a failure of the power supply.

Mr. Browne, who, on account of his nickel-copper process, stands in the front rank of electrometallurgists of the world, has formerly pronounced very concisely and cleverly the fundamental keynote of the successful working of an electrolytic process by emphasizing that initially good conditions should be maintained good during operation. Let us apply this requirement, to the whole plant. It was designed for a certain number of tanks, and provided with a dynamo designed to furnish current for that number. The first requirements of successful working—the initially good conditions—were thus provided, but at the start of operation the number of tanks was changed; this reacted upon the dynamo. It is, of course, very easy to point out such general morals of a story—much easier than it was for the four dynamo and engine experts to find the cause. Mr. Browne's switch, by which the proper exciting current for the field of the dynamo is provided under different conditions of operation, is instructive in showing how it is nearly always possible to rectify matters after one has clearly recognized where the fundamental weak point lies.

ESTIMATING THE OXYGEN CONTENT IN COPPER.

In this issue we publish a fully illustrated account of an extended investigation by Messrs. H. O. Hofman, C. F. Green and R. B. Yerxa, on the microstructure of alloys of copper and cuprous oxide. While the subject is not directly of an electrochemical nature, yet we have no doubt that this paper will be read with much interest by our copper refiners, and, in fact, by every copper metallurgist. It becomes daily more evident that metallographical principles and methods are not only of great scientific interest, but may be made use of to good advantage by the practical metallurgist. The results obtained by Messrs. Hofman, Green and Yerxa are suggestive in this respect. They show that area-measurements of enlarged micrographs of pure coppers containing less oxygen than the eutectic give good valuations of the oxygen-content. Moreover, it seems entirely feasible to make quickly a close estimation of the percentage of cuprous oxide contained in a sample of copper by simply examining a polished surface with the microscope, when once some experience has been gained.

THE CONSTITUTION OF SALT SOLUTIONS.

The Synopsis of this issue contains an abstract of an interesting and suggestive paper of Prof. Abegg, on one of the most fundamental points of the electrolytic dissociation theory. This fundamental point is the determination of the chemical nature of the ions in the case of a given solution. This has always been to some extent a weak point of the theory, in so far as no exact method was known by which one could determine in any case what the ions are, without making more or less arbitrary assumptions. What is best known of the ions, is their properties—their electric charge and their mobility in infinitely dilute solutions. When we adopt the scheme of traveling ions for describing and illustrating the electric phenomena in a solution, we *must* attribute to each monovalent gramion a charge of 96,540 coulombs, and to any ion in an infinitely dilute solution a distinct mobility, dependent only on its own chemical nature. In attributing these two properties to the ions, we do not make any arbitrary assumption, but simply express, in the language of the scheme of ions, the facts given in Faraday's law and ascertained by Kohlrausch in his conductivity measurements with dilute solutions.

It is quite different with the other question; when we have a solution of a given compound in a given solvent, what is the anion and what is the cation? If we only want to know how much of a given substance is deposited or dissolved, etc. by a number of ampere hours in a given cell, the question what the ions are is of no great account, since various assumptions may lead to the same result. This is the reason why, in the past, for a long while many people found it convenient to assume that in an aqueous solution the hydrogen and the

oxygen of the water are the ions; for instance, the reaction of the lead accumulator was often described as though during discharge the lead peroxide was reduced by nascent hydrogen to oxide and the spongy lead was oxidized by nascent oxygen to oxide, the oxide then being secondarily changed into sulphate at both ends; as long as we only want to know how many grams of any substance are changed by a given number of ampere hours, this view gives correct numerical results. Nevertheless, there is an extended series of facts, which have been ascertained, beginning with and since Faraday, and which speak against such an assumption. In fact, in the evolution of the ionic idea we have gradually been led to the exactly opposite assumption that the water practically forms no ions, and that it is the dissolved substance which is ionized.

In the development of this idea, it was then possible to a certain extent to determine experimentally something concerning the chemical nature of the ions. For instance, by his transference number measurements, Hittorf could show that in certain double salts the one metal must be assumed to be contained in a complex anion. Further, if we consider simple salts, for instance all chlorides, in very dilute solutions, then Kohlrausch's measurements show that the anion in infinitely dilute solutions of all chlorides has exactly the same mobility. We therefore conclude that the anion in all dilute chloride solutions is of the same chemical nature, and—on the basis of the hypothesis that it is the dissolved salt which is ionized—we conclude that the anion of any chloride is the chlorine ion, *i. e.*, a negatively charged chlorine atom (or, if we prefer to say so, a compound of a chlorine atom and a negative electron). For more concentrated solutions we assume with Arrhenius that the anion remains of the same chemical nature, and that only the number of the ions (or the number of the ionized molecules of the dissolved substance) changes. What we wish to point out here is that the above fundamental conclusion concerning the chemical nature of the anion in a chloride solution is to some extent arbitrary, *i. e.*, it goes beyond what has actually been determined by experiment. True, in infinitely dilute solutions, we have no right to assume that the anion is chemically a compound of chlorine with molecules of the dissolved substance, since the mobility of the anion is the same for the different chlorides. But so far as the facts have been ascertained, nothing would prevent us from assuming that the anion is some compound of chlorine with water, which is the common solvent. This would lead to a combination of the ideas of the dissociation and association theories, which is in itself not foolish, and which, for more concentrated solutions, at least, has certain facts in its favor.

The leading principle, on which, in the past, all assumptions concerning the chemical nature of the ions were based, was to make the theory as simple as possible; in the case of chlorides the simplest assumption is that chlorine is the anion. This is not said in any derogatory spirit. In the evolution of any theory it is natural to proceed in such a way that one first makes the simplest assumptions and modifies them later, when necessity arises. This has naturally been the case with the dissociation theory, and is well illustrated by the paper of Prof. Abegg. While in full agreement with the assumption that it is the dissolved salt which is ionized, he shows that not all the ions can be of such a simple nature as is generally assumed, and that complex ions must be assumed to exist even in ordinary simple solutions to a far greater extent than might have been expected. Hittorf had already shown that in a solution of $CdCl_2$, there are not only the simple ions $Cd^{\cdot\cdot}$ and Cl', but a considerable number of complex anions of the general formula $(CdCl_2)n\ (Cl')m$. Arrhenius was later led to similar conclusions in other cases in which comparisons of freezing point with conductivity measurements did not agree with his fundamental hypothesis. Abegg and Bodlaender had found that the formation of complex ions is a characteristic feature of double salts; and since the constituents of a complex ion—the simple ions and the not-ionized molecules—exist in the solutions of simple salts, Abegg concluded that complex ions must also exist in the solutions of simple salts. This conclusion was confirmed by his experiments.

The principle of Abegg's investigation is as follows. From conductivity measurements we can find the total number of simple and complex ions. If we now have a method of determining by another method the number of the simple ions alone, we will find to what extent complex ions exist in the solution. The method of determining the number of simple ions of a metal in a solution of a salt of this metal is to measure the potential of an electrode of this metal in the solution (against a normal electrode); by means of Nernst's theory of the e. m. f. of a reversible electrode, the concentration of the simple metal ions in the solution may then be determined. The results of Abegg's investigation are of great interest; they are to the effect that complex ions must be assumed to exist to a large extent in acetates, sulphates and chlorides, and to a smaller extent in nitrates; the metals, the salts of which were examined, being zinc, cadmium, iron, cobalt, nickel, lead and copper. The results are in agreement with what Abegg had expected from his and Bodlaender's theory of electroaffinity.

On the other hand, it is undeniable that to obtain a full proof of Abegg's views, it would be necessary that the numbers of the complex ions are determined by another, different method, and shown to agree with the values found in the first method. As long as this is not done, the only absolutely certain conclusion to be drawn from Prof. Abegg's investigation is that the ordinary assumption (that, for instance, an aqueous solution of zinc sulphate contains only water, zinc sulphate molecules, zinc ions and SO_4 ions) leads to conclusions which are not in agreement with the facts. This is, however, something we already know from the extended researches of Kahlenberg, although Kahlenberg draws a quite different conclusion from the existing disagreement than Abegg does. Abegg assumes the existence of complex ions, being essentially a compound of simple ions with neutral salt molecules. Kahlenberg emphasizes the importance of the chemical affinity between solvent and solute. It is evident that before a decision can be reached, much more experimental facts are to be ascertained.

INTERNATIONAL ELECTRICAL CONGRESS.

As was noticed in our last issue, everything points to a very great success of the International Electrical Congress, which will be held at St. Louis from September 12 to 17, 1904. The number of persons who already have applied for membership is more than sufficient to make a success certain, while more applications for membership are daily coming in, especially from abroad. Collection of fees has commenced, and upon receipt the member is forwarded a certificate of membership, a reproduction of which is shown herewith, since, by a mistake, it was omitted in our last issue. The certificate is 8½ inches by 11 inches in size, and printed on heavy paper. All communications should be addressed to the general secretary, Dr. A. E. Kennelly, Harvard University, Cambridge, Mass.

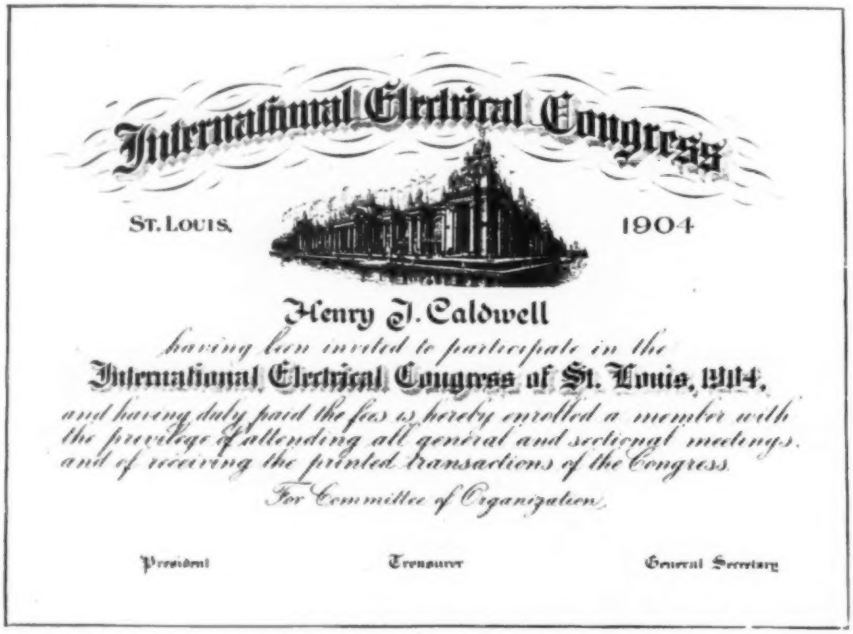
FARADAY SOCIETY.

A meeting of the (British) Faraday Society was held on February 2, in London, the president, Dr. J. W. Swan, being in the chair.

Mr. Jonas read an abstract of a paper by Mr. S. Cowper-Coles, entitled "Notes on the Welding of Aluminium." Soldered aluminium joints have proved unsatisfactory, as they will not stand the test of time. One of the chief difficulties encountered other than the formation of oxide in soldering aluminium is, that a few degrees below its welding point it passes into a pasty or brittle state, and being a very good conductor of heat, the solder very rapidly cools and freezes before it has time to flow sufficiently. He described various machines and processes for welding aluminium, and then went on to describe his own process, which was already noticed on page 31 of our January issue.

In the discussion which followed, Mr. D. A. Sutherland said that the principle of the method was familiar to metallurgists who had to report on these matters; the great difficulty was where large pieces of aluminium had to be welded. Mr. M. Morrison agreed with the last speaker; he, himself, had welded many joints in this way, although he did not quench. He always found that pressure was necessary; the chief novelty of the Cowper-Coles process lay in the apparatus. Mr. B. Blount said when drawn wires were welded it was essential that the joint be drawn or worked in some way, otherwise, being cast metal, it would be weaker than the rest of the wire. Prof. Huntington thought that the chief novelty in the process lay in the fact that the metal was actually fused. Mr. E. K. Scott said that the important point to remember was the value of the hard outer skin of the metal. If aluminium wires were used for transmission of electricity, uniformity of section was unimportant, and the blob at the weld need not be removed. But otherwise, *e. g.*, if used as trolley wires, it would be necessary to harden the joint in some way; this might be done by burnishing with agate. He showed by a diagram how a connection might be made without welding. Mr. Jonas, in reply to Mr. Blount, said that the joints proved to be the strongest part of the rods. He would remark that the quenching was an essential feature of the process, and one which distinguished it from all others, the process being primarily a fusion process.

Dr. F. M. Perkin then read an abstract of a paper by M. Hollard, entitled "Some Applications of the Theory of Electrolysis to the Separation of Metals from One Another." An abstract of this paper is given in the Synopsis of this issue.


International Electrical Congress
St. Louis, 1904
Henry J. Caldwell
having been invited to participate in the
International Electrical Congress of St. Louis, 1904,
and having duly paid the fees is hereby enrolled a member with the privilege of attending all general and sectional meetings, and of receiving the printed transactions of the Congress.
For Committee of Organization.
President Treasurer General Secretary

CERTIFICATE OF MEMBERSHIP, INTERNATIONAL ELECTRICAL CONGRESS.

Mr. G. Watson Gray read a short preliminary note describing an explosion of some high-grade ferro-silicon that occurred spontaneously a short time ago at Liverpool. The gases evolved on boiling a specimen in distilled water were found to contain PH_3 and AsH_3. The former was in the greater proportion, and to that probably the explosions were due.

Mr. D. A. Sutherland thought that the presence of only 0.1 per cent phosphorus made it very difficult to account for the explosions being due to phosphoretted hydrogen. It was essential to know the previous history of the metal. Mr. R. H. Harland and Mr. E. K. Scott, who had gone into the matter, believed the explosion was due to calcium carbide, which had been previously made in the same furnace.

Mr. Gray, in his reply, said there was certainly less than 0.1 per cent of calcium in this particular specimen of ferro-silicon. There was no doubt as to the presence of phosphoretted hydrogen in the gases evolved. He would report further in the matter, and Mr. Harland promised to do the same.

ELECTROPLATING UPON ALUMINIUM.

BY CHARLES F. BURGESS AND CARL HAMBUECHEN.

A review of the many contributions to electrochemical literature concerning the subject of electroplating upon aluminium might lead to the belief that if electroplaters would but follow the directions given therein for obtaining durable, adherent coatings of gold, copper, nickel and various other metals upon aluminium they would encounter no difficulty. Most of the articles dealing with the question refer to it as a hitherto unsolved problem, explain why it is difficult to plate upon aluminium, and then give instructions for operating so that such difficulties may be overcome. Unfortunately, the records stop at this point, and fail to recite the experiences and the results attained in the various attempts that are made to follow such directions.

Adhering to the general formula for contributions on this subject, the authors may state that their attempts to follow many of the published instructions have failed to produce satisfactory results, and that they were thus led to undertake experimental investigation, with results of such a degree of success that they feel warranted in adding further to the literature on hand.

The principal difficulty encountered in the deposition of a metal coating upon aluminium is as regards its adherence. The mistake is commonly made of assuming that a test of this property is complete when the article taken from the plating-tank is subjected to a buffing or polishing operation. The coating must, however, stand the test of time and the chemical and mechanical wear which time and use bring. The adherence may be all that is desired for the first few days or even months, but if the coating is not sufficiently dense and continuous to exclude moisture it may become loose after a certain lapse of time. Deposits which were obtained in the manner described further have now stood the test of over a year's time without an apparent deterioration.

It is generally agreed that the difficulties of plating on aluminium are attributable to the invisible film which forms upon that metal when exposed to the atmosphere or to almost any aqueous solution. Most of the methods recommended for plating require the removal or dissolving of this film by one of the various solvents, such as hydrochloric acid, hydrofluoric acid, or the alkaline hydrates, and the rapid transferrence of the article thus cleaned to the rinsing and then to the plating tank.

The ideal method which naturally suggests itself is, after cleaning the metal by the means suggested, to immerse it in a plating solution of a composition that will act as a solvent for any film that might tend to be formed. In other words, if the plating solution could act as a solvent for the film of aluminium oxide or hydroxide, and at the same time furnish the proper metal ions the elimination of the film difficulty would be ensured.

During the trial of a great many solutions to find one which would combine these properties in a sufficient degree, the best results were obtained by the use of a soluble fluoride in the plating bath. Such fluorides may be present as a sodium, potassium, or ammonium salt, or perhaps preferably as a small quantity of free hydrofluoric acid. Since the fluorine compounds of many of the metals are insoluble, a fluoride cannot be maintained in solution in many of the plating baths. In certain ones, however, notably in zinc sulphate solutions, the precipitate which is first formed on the addition of a small quantity of sodium fluoride or hydrofluoric acid becomes dissolved on standing, and it is from such solutions that adherent deposits may be obtained.

We have noted that certain of the metals have the property of adhering more tenaciously to aluminium than do others, due, possibly, to differences in alloying property, or to the intimacy of contact which can be made between the two metals. Zinc seems to possess the adhering property to a high degree, and consequently the use of this metal is recommended. After once obtaining such adherent deposit of zinc, the article may be transferred to another plating solution from which the finishing coating of the desired metal may be obtained. A disadvantage in the use of zinc as a preliminary coating was found in depositing a layer of gold upon it. While the product seemed at first to be highly satisfactory, the gold disappeared almost completely within a few weeks' time, being absorbed or alloyed by the zinc. This difficulty was overcome by giving the zinc a thin coating of copper from a cyanide solution before applying the gold.

The mode of operation which may be recommended is to first clean the aluminium by immersion for a few minutes in a dilute hydrofluoric acid bath where it remains long enough to produce a suitable roughening of the surface. The deposition upon a rough surface is more adherent than upon a polished one, and this step is therefore of importance. Upon removing the aluminium from this bath it is rinsed in running water and then dipped for a few seconds in a mixture of 100 parts of sulphuric acid and 75 parts of nitric acid, both concentrated, from which, after rinsing in water, the aluminium comes perfectly white and clean. If an impure aluminium or aluminium alloy be treated, it may have a loosely adhering black coating on leaving the hydrofluoric acid dip, and this may be removed satisfactorily by brushing before placing it in the final acid dip.

The aluminium after being thus cleaned is transferred to the zinc plating solution. This consists of a mixture of zinc and aluminium sulphates in the proportion commonly used for zinc plating, very slightly acidified and having a density of about 15 degrees Baume and containing about 1 per cent of hydrofluoric acid or an equivalent amount of potassium fluoride.

While it is desirable that the article be transferred from the cleaning solution into the plating bath without unreasonable delay, it is not essential that it be done with great rapidity, since the plating solution acts also as a cleaning one. After the deposition has proceeded for about ten or fifteen minutes with a current density of from 10 to 20 amperes per square foot, the article may be taken from the solution and dried. It may then be given a coating of copper or silver from their cyanide solutions, using such precautions as are commonly observed in the deposition of such metals upon zinc.

Where the final coating is to be of gold, it may be advantageous to polish the copper coating before depositing the gold, as otherwise a thicker gold coating will be necessary to produce the final polish. It will be seen that by this method of operation the deposition of gold upon aluminium is a somewhat involved process, requiring the preliminary deposition of two different metals upon the aluminium before the final coating of gold is applied, but the exceedingly rapid manipulation required by various other metals is eliminated. The adherence and durability of the final coating depends almost entirely upon the adherence of the aluminium for the zinc. It is to this part of the process that the suggestions herein given specifically refer. Various modifications of the methods of manipulation for the purpose of economy of time and labor may be apparent to the electroplater, and may be employed without departing materially from the principles described.

Applied Electrochemistry Laboratory,
University of Wisconsin.

AMERICAN ELECTROCHEMICAL SOCIETY.—The next general meeting of the American Electrochemical Society, which will be the annual meeting, will be held in Washington, D. C., from April 7 to 9. The second general meeting of this year will probably be held in connection with the International Electrical Congress in St. Louis.

WHAT AILED THE DYNAMO?

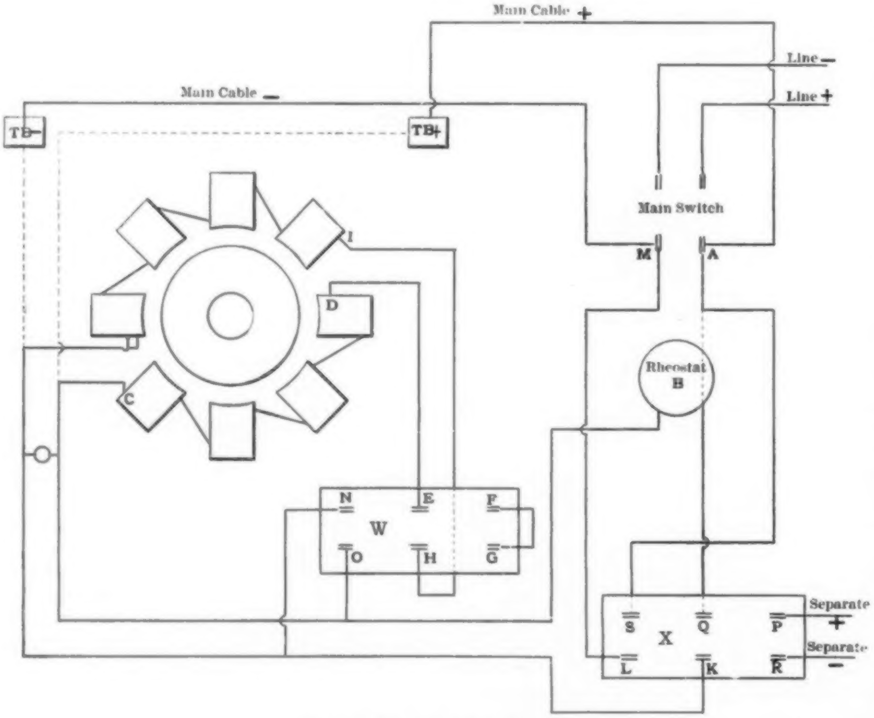
By D. H. Browne.

In starting any electrolytic process the troubles which are most perplexing are usually those arising from the dynamo and engine. It is not always possible to start working with exactly the load for which the dynamo is designed. Circumstances necessitate the cutting out of baths which are not working properly. This alters the total line resistance, causes weakening of the magnetic field, and consequent sparking at the commutator, and the man whose entire attention should be given to the proper conduct of the electrolytic operations is suddenly confronted with mechanical and construction problems, often simple enough, but with which he has had little previous experience. To those who have struggled with these difficulties the following notes, collected from the journal of a refining plant, may be of interest.

The dynamo was a new eight-pole, carbon brush, bar commutator machine, built by a large and well-known electrical manufacturing concern, and stated, when purchased, to give at 255 revolutions per minute, 900 amperes at 40 degrees rise of temperature and 1000 amperes with 50 degrees rise. The rated pressure was 120 volts.

This was direct-connected to a new engine $16\frac{1}{2}$ by 16 inches, made by a well-known engine-building firm. The foundations were exceedingly solid, being constructed of one block of concrete. All alignments were most carefully adjusted, and the dynamo tested with a water load before starting the process; so that there was no reason whatever to apprehend any trouble from the dynamo or engine.

On starting the process it was found necessary to cut out some of the baths whereby the line voltage was cut from 120 to 80 volts. This caused sparking at the commutator, which for two months was a continuous source of annoyance, as the journal records show.



CONNECTIONS OF DYNAMO.

Self-Excited Series Field—A B C D E F G H I J K L M.
Self-Excited Multiple Field—A B C D E N K L M and A B O H I J K L M.
Separate-Excited Series Field—P Q B C D E F G H I J K R.
Separate-Excited Multiple Field—P Q B C D E N K R and P Q B O H I J K R.

January 27, 1901. The dynamo is giving 900 amperes at 90 volts. Sparking under all the brushes. The commutator is again cutting very badly. The engineer was about to turn it off for the third time. Stopped him, as there is no use doctoring symptoms. Wired the electrical company who had built the dynamo to send an expert on the first train.

January 29. Electrical expert arrived; spent all afternoon testing the dynamo and looking for "grounds" in the plating room.

January 30. Expert turned off the commutator and is setting the brushes very exactly. After to-day's dressing down I find commutator has lost 5-16 of an inch diameter in three months.

January 31. Running the dynamo last night and to-day 900 amperes—90 volts. Continuous sparking under all the brushes. Electrical expert says the dynamo is all right, but the engine runs with a jerk. Had the engineer take an indicator card—which certainly looks smooth enough. Telephoned into town for an expert engineer. He came out at noon, and says there is a very slight disturbance in engine, but not enough to cause all this trouble. Both men agree to leave dynamo running over Sunday to see where or why the cutting occurs.

At noon to-day had to stop the dynamo a few minutes. When we started the current was reversed. Noticed that the engineer threw in the resistance coil of the shunt-winding, so as to cut the voltage down before he threw the circuit breaker and pulled the main switch. He should have left the rheostat alone. When the current is on we have line resistance of 90 volts. When the current is off each bath acts like a storage battery, and sends out a reversed current, of about 1.1 volts per bath; giving a total back pressure of 27 volts. With the rheostat cut out the easiest path for this current is back through the field coils—and this, of course, magnetizes the poles in the reverse direction.

To remedy this, disconnect the shunt winding so as to cut the field coils off the main leads. Connect the positive wire from the electric light dynamo to the positive end of the field coils and the negative wire to the opposite side. Lead a current of 10 or 15 amperes through this field winding for two or three minutes. Then slow down the light machine and stop it. Do not break the switch of the light machine while the current is flowing through the field of the big generator or the coils will act like a big induction coil and throw a spark that may burn the insulation. Disconnect the light machine and reconnect the field coils with the main lead.

To prevent this, always keep the voltage on switchboard higher than the back pressure. When the dynamo is to be stopped leave the rheostat alone and throw the circuit breaker with full load on. Then pull the main switch and slow down

the engine. This is all very well to know, but it has nothing to do with the commutator trouble.

February 1. The dynamo is still sparking and both experts are still thinking.

February 2. Dynamo is in a bad way. Tried cutting out the shunt and using separate exciting current, but the sparking under each brush is just as bad as ever. Experts went home still thinking. One blames the dynamo, the other condemns the engine.

February 8. The commutator has cut so that the engine room sounds like a thrashing mill. Brushes chatter so that chips of carbon half an inch square fly off. The cutting is on each segment. None are particularly worse than the other, so it cannot be a bad insulation in the commutator.

Electrical expert No. 2 came to-day with a whole bag of tricks to test the insulation.

The trouble simmers down to this: The electrical men say there is a "knock" in the engine. The engine men say the engine is all right, but the trouble is in the generator. Our engineer splits the difference and thinks it is in the flywheel. Telephoned the factory, and they say the fly-wheel was turned to a pound before it left the shop. Took this day a high and holy resolve never again to buy a dynamo from one firm and an engine from another. Get them both from one firm, and then the makers can't indulge in mutual recriminations.

February 9. Engine expert No. 2 out to-day. Took the engine to pieces and ran a fine wire through the centers; find all bearings absolutely true. Got the electrical men to admit this once for all.

February 10. Big job to-day getting engine on its feet again.

February 11. Ran engine to-day to convince the electrical men that it was running smoothly before we started the dynamo with a load. The electrical chief expert wants to turn the commutator off again. Made strenuous objection to doctoring symptoms any more. He says if we turn it off again and the thing still sparks his firm "will take very radical measures." This sounds mysterious, but comforting. Went ahead and turned the commutator. The poor thing begins to look thin.

February 13. Electrical man is digging with a putty knife between the commutator segments. He does not say much. Got load on 80 volts, 900 amperes. Sparked as badly as ever. Expert made some lightning changes from shunt to compound winding and back again, cut current down to 700 amperes. This stopped sparking, but will not do, as we want 900 amperes, not 700.

February 15. 900 amperes on, still sparking. Tried a water load to see what different engine speeds would do.

At 228 revolutions we get 120 volts, 700 amperes, with slight sparking. At 244 revolutions we get 125 volts, 880 amperes, and increased sparking. At 250 revolutions, 125 volts, 1000 amperes, and sparking as badly as ever.

February 16. The electrical man sees a great light; as nearly as I can comprehend his reasoning, it is as follows.

The machine is so designed that when the line pressure is 125 volts, about 15 amperes pass around the field coils. If we have only half the line pressure we get only 7 amperes around the shunt winding, and the field is very weak. We have very much less line resistance than the machine is designed for; hence, the field coils do not receive sufficient current. With this work the amperage should be constant, while the voltage changes with the number of baths in series. We have been keeping the machine at its rated speed while we have been producing a lower voltage, and hence a weaker current in the field coils than the machine is designed for. To tide over a day or so, electrical expert has taken a separate exciting current of about 12 amperes from the electric lighting machine. He has cut the engine to 220 revolutions per minute. We are getting 850 amperes at 70 volts. The current is not quite high enough, but the brushes have ceased sparking, and sweet peace begins to brood over the engine room.

February 17. Electrical expert suggests that when we have less line resistance than the dynamo was designed for we run the engine proportionately slower, and since this cuts down the voltage and the current going round the field coils is proportional to this voltage, we decrease the resistance of the field coils by connecting them in two multiples of 4 poles in series, instead of all eight poles in series. This will cut the resistance of the field coils in two, and so, by doubling the current which flows through them, we will be able to get a strong field with much less line voltage.

February 18. Electrical expert has gone home. He says the engine was all right, and the trouble was all due to weak field. The dynamo is running without spark at 900 amperes, 70 volts. For this relief, much thanks.

We are fitting up two switches. One of these W connects the field coils either in series or multiple. The other X throws either a shunt current or a separate exciting current around the field coils. With self-excited series field the path of the current, as shown in the diagram, will be A, B, C, D, E, F, G, H, I, J, K, L, M.

This current will be used when the generator is running within 25 per cent of its indicated voltage. When the voltage falls to 50 per cent of the indicated amount the multiple field is to be used, but the rheostat must be cut out. The path of current is then A, B, C, D, E, N, K, L, M and A, B, O, H, I, J, K, L, M.

If, however, the dynamo reverses we use separate exciting current, the path of which in series field is as follows: P, Q. B. C. D. E. F. G. H. I. J, K, R.

If a separate exciting current of 5 to 8 amperes is used, the multiple field may be used, the current paths being, P, Q, B, C, D, E, N. K, R, and P, Q, B, O, H, I, J, K, R.

The blocks marked TA and TB are the main cable connections at the base of the dynamo.

These switches were put in operation and the dynamo worked continuously without giving any further trouble.

A LABORATORY STUDY OF THE STAGES IN THE REFINING OF COPPER[1]

BY H. O. HOFMAN, C. F. GREEN AND R. B. YERXA.

INTRODUCTION.

In refining copper, the metal is melted down in a reverberatory furnace in a more or less oxidizing atmosphere and then further subjected to an oxidizing smelting in order to eliminate the common impurities, most of which have a stronger affinity for oxygen than has copper. In these operations some of the copper is oxidized to cuprous oxide and dissolved by the metal bath. When the quantity of dissolved cuprous oxide has reached about 6 per cent, the metal is said to have been brought to "set-copper." A button-sample will show a depressed surface and, when broken, a single bubble at the apex of the depression; the fracture will be brick-red and dull. It is essential to carry the oxidation to this point in order to know that the impurities have been oxidized as far as it is possible under the given working-conditions. Nearly all the cuprous oxide of the set-copper is now reduced to the metallic state by poling, when "tough-pitch" copper will be obtained. A button-sample will show a flat surface. Upon breaking, it will be found that the former bubble has disappeared and that the fracture has become rose-colored and shows a silky lustre. The quantity of cuprous oxide allowed to remain in the copper will vary with the impurities still present in the metal and with the degree of pitch that it is desired to reach. It is essential for the general physical and the mechanical properties of the resulting copper that such impurities as arsenic, antimony, bismuth[2], lead shall be present in the oxidized state, as they are

[1] A paper presented to the American Institute of Mining Engineers.

[2] This generally accepted statement by Hampe (Zeitschrift für Berg-, Hütten- und Salinen-Wesen im Preussischen Staate, 1874, xxii., 121) is doubted by Roberts-Austen (Journal of the Society of Chemical Industry, 1894, xiii., 471), who, in discussing Gowland's paper, "A Japanese Pseudo-Speise (Shiromé)," etc., says, "however small the proportion of bismuth in copper might be, it always remained free, and did not unite with the copper."

then less harmful than when present in the metallic state. Refiners commonly distinguish "ingot- or cake-pitch" and "wire-bar pitch;" copper brought to the former contains more cuprous oxide than the latter. These two pitches are, however, not absolutely fixed; they vary with the practice of the individual refiner and with thickness of the cake or bar that is to be cast: The thicker the piece, the more ozygen will have to remain in the metal, if a flat surface is to be obtained. A third degree of pitch aimed at is that required by very thin castings, such as electrodes 0.5 inch in thickness. As this pitch lies beyond that of wire-bar copper and differs from it more than to permit its being designated merely a shading, it may be called "plate-pitch."

TABLE I.—Results of Heyn's Experiments.

Test No.	Charge.		Crucible, Lined or Not Lined.	Cu_2O Calculated from O Found by Analysis. (a)	Temperature of Solidification.		Observations on the Galvanometer.
	Cu Grams.	Cu_2O Grams.			Beginning.	Ending.	
				Per Cent.	Degrees Centigrade.	Degrees Centigrade.	
1	450	None.	Not lined.	0.08	1102	....	Decided retardation at 1102° C.
2	450	?	Lined.	1.16	1095	1085	Long retardation at 1095° C., slow fall to 1083° C., quick rise to 1085° C., long retardation, slow, followed by quick, fall.
3	450	9.0	Lined.	1.75	1089	1084	Slow fall, beginning at 1089° C., retardation at 1086° C., slow fall to 1083° C., sudden rise to 1084° C., long retardation, slow, followed by quick, fall.
4	450	22.5	Lined.	3.4	....	1084	Fall to 1076° C. without any retardation, sudden rise to 1084° C., long retardation, slow, followed by quick, fall.
5	450	18.0	Lined.	3.5	....	1084	Fall to 1082° C. without any retardation, sudden rise to 1084° C., long retardation, slow, followed by quick, fall.
6	450	27.0	Lined.	4.7	1116	1084	Slow fall, beginning at 1116° C., very slow fall to 1076° C., sudden rise to 1084° C., long retardation, slow, followed by quick, fall.
7	450	40.5	Lined.	6.3	1149	1084	Slow fall, beginning at 1149° C., very slow fall to 1077° C., sudden rise to 1084° C., long retardation, slow, followed by quick, fall.
8	450	60.0	Lined.	9.0	1186	1084	Slow fall, beginning at 1186° C., slow fall to 1079° C., sudden rise to 1084° C., long retardation, slow, followed by quick, fall.

(a) Reduction by means of hydrogen: "Hampe's Method," Zeitschrift für Berg-, Hütten- und Salinen-Wesen im Preussischen Staate, 1873, xxi., 231.

Little was known of the structural relations that existed between copper and cuprous oxide until 1900, when Heyn[2] published the results of his investigations on "copper and oxygen." He took pure copper wire, cut it into small pieces, made up charges of 450 grams each, added to them varying quantities of pure cuprous oxide, melted the mixtures (excepting sample No. 1) in graphite crucibles lined with porcelain, inserted into the fused charges the protected couple of a Le Chatelier thermo-electric pyrometer and made the cooling-curves. Sample No. 1, copper wire alone, was fused in a graphite crucible without a lining in order that the graphite might have a reducing effect upon the small quantity of oxide present, and the resulting fused copper be as free from it as was possible. The results of his experiments are given in Table I., which are represented graphically by the freezing-point curve in the subjoined diagram.

It will be seen from Table I. that upon cooling, only the tests Nos. 1, 4 and 5 show a single fall of temperature, which means that they do not pass through a pasty stage, but freeze suddenly. With the other tests there is a gradual freezing from the beginning to the end of the solidification. With all samples, excepting test No. 1, the cooling is accompanied by surfusion, the depressed temperature rising in every instance to the fixed point of 1084° C. This temperature, corresponding to the freezing-points of tests Nos. 4 and 5 containing 3.4 and 3.5 per cent. Cu_2O respectively, which have only one distinct point of solidification, must be the temperature of the eutectic. The V-shaped freezing-point curve of the diagram, plotted from the data in Table I., and the micrographs, Figs. 1 to 8 inclusive, bring this fact out clearly. Figs. 4 and 5, the eutectic of copper and cuprous oxide with 3.4 and 3.5 per cent. Cu_2O respectively, show the characteristic structure, *i. e.*, a conglomerate of the two components arranged more or less in alternate plates which do not cross one another. With alloys of diminishing percentages of cuprous oxide, shown in Figs. 3, 2 and 1, the micrographs give the dark network of eutectic and the light mesh-work of copper; with alloys having percentages of cuprous oxide greater than 3.4 or 3.5, the micrographs, Figs. 6 and 7, show patches of cuprous oxide increasing in size embedded in eutectic mixture.

The alloys of copper and cuprous oxide, when in the molten state, form homogeneous solutions similar to salt solutions. Upon the solidification of copper-alloys containing less than 3.45 per cent Cu_2O, the cuprous oxide falls out completely and does not form a solid solution with copper. This is seen clearly in Fig. 1, where the network of the eutectic is still visible, when the copper contains only 0.08 per cent Cu_2O. Should any cuprous oxide form a solid solution, its quantity would have to be less than 0.08 per cent. Whether in an alloy with more than 3.45 per cent Cu_2O, the patches of cuprous oxide (Figs. 6 and 7) are pure cuprous oxide, is not settled, but in all probability this is the case.

Finally, Fig. 8 represents the same sample as shown in Fig. 2, *viz.*, copper with 1.16 per cent Cu_2O. In the first case, the specimen has been heated to 1100° C. and then quenched in water of 10° C.; in the second, it has been allowed to cool slowly. The disconnected points in the micrograph of the quenched specimen show how the free development of the inner structure has been arrested; in contrast, Fig. 2 illustrates clearly how the eutectic, if given sufficient time, forms a connected network.

The leading statements of Heyn's paper, including eight of his nine micrographs, have been repeated here, for the reason that they have an important bearing upon the work to be described; in fact, the suggestion in his conclusions that observation of the microstructure of refined copper might be substituted for the lengthy determination of oxygen was the cause of undertaking the present investigation. This embodies the examination of fractures of samples taken in different stages of refining, the determination of the oxygen-content, the preparation of micrographs, and, lastly, the planimetric measurement of enlarged micrographs, with calculation of the percentage of oxygen.

Description of Samples.

Button-samples for this investigation were kindly furnished by Mr. W. T. Burns, of the Boston & Montana Consolidated Copper and Silver Mining Co., Great Falls, Mont., by Mr. M. B. Patch, of the Buffalo Smelting Works, of the Calumet & Hecla Mining Co., Buffalo, N. Y.; and by Mr. G. M. Luther, of the Nichols Chemical Co., Laurel Hill, N. Y.

Sample No. 1 of the Boston & Montana Co. represents cathode copper after it has been melted down in the reverberatory furnace and skimmed, but not rabbled; No. 2 was taken after the rabbling had been completed and the stage of set-copper reached; No. 3 is the sample after the poling has been finished, and the copper is ready to be ladled into wire-bars. The tests made at the works give: silver, 0.8 ounces per ton; arsenic and antimony, 0.0035 per cent; conductivity,

[2] Mittheilungen aus den Königlichen Versuchsanstalten zu Berlin, 1900, xviii., 315; see also The Metallographist, 1903, vi., 49.

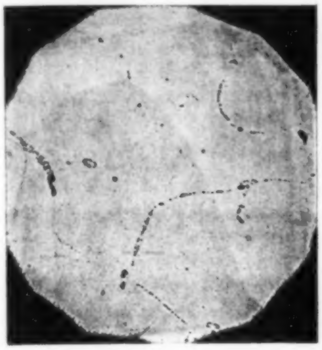


Fig. 1.

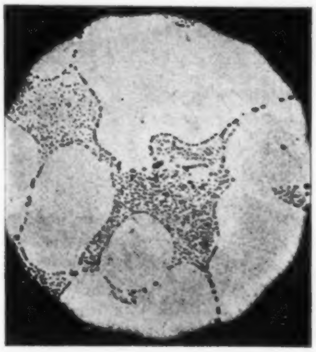


Fig. 2.

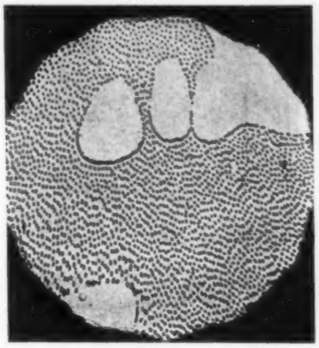


Fig. 3.

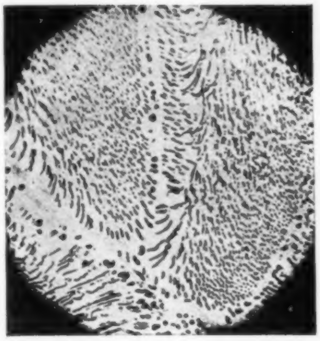


Fig. 4.

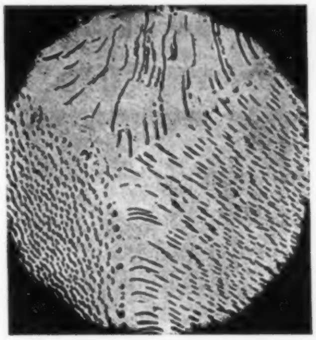


Fig. 5.

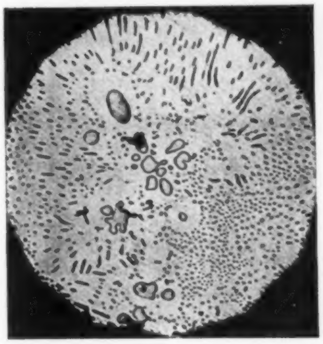


Fig. 6.

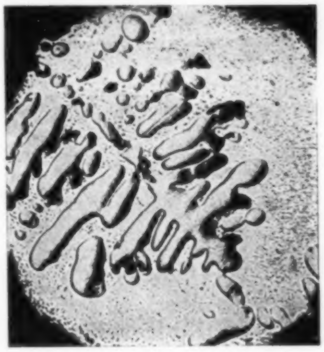


Fig. 7.

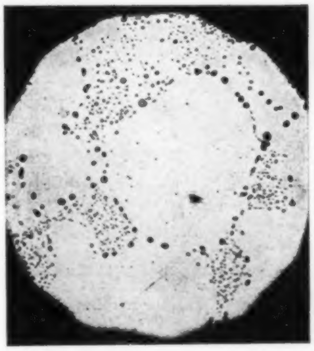


Fig. 8.

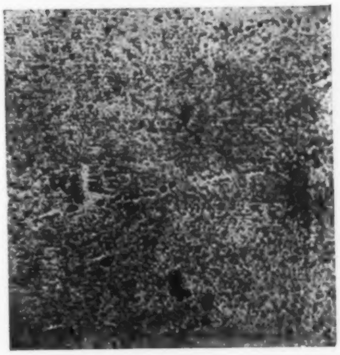


Fig. 19.

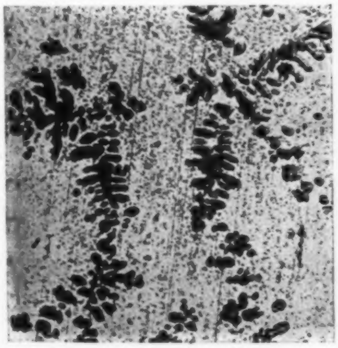


Fig. 20.

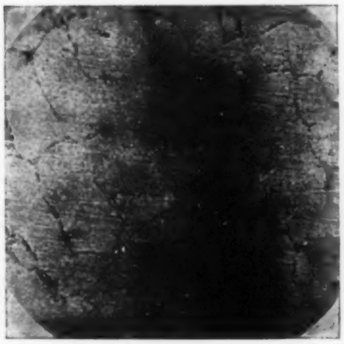


Fig. 21.

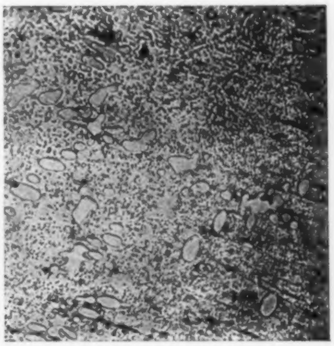


Fig. 22.

Figs. 1 to 8, Copper-Cuprous Oxide Alloys (Heyn), Magnified 123 diameters.

Figs. 19, 20, 21, Samples 1, 2, 3, Boston & Montana copper, containing 3, 6.16 and 0.51 per cent Cu_2O, respectively. Magnified 100 diameters.

Fig. 22.—Sample O, Calumet & Hecla Set Copper, 5.76 per cent. Cu_2O. Magnified 100 diameters.

97.5 per cent; tensile strength, 64,200 pounds per square inch; elongation, 1 per cent; torsion-twists in 6 inches, 89.

Sample No. 0 of the Buffalo Smelting Works represents set-copper; the remaining six of the set, Nos. 1, 2, 3, 4, 5 and 6, were taken at intervals of fifteen minutes during the poling-period: No. 1 was cast after the poles had been in the furnace for fifteen minutes; No. 6 is finished refined copper brought to a pitch at which ingots or cakes are cast. Samples Nos. A and B, from another charge, represent copper brought to ingot-pitch and wire-bar pitch respectively, special care having been taken to allow the samples to cool slowly.

The sample of the Nichols Chemical Co. represents plate-pitch, *i. e.* the pitch desired for casting thin electrodes.

FRACTURES OF SAMPLES.

The fractures reproduced in Figs. 9 to 18, inclusive, were prepared in the usual way. An incision about 0.125 inch in depth was made across the convex side of a button with a cold-chisel, the button then clamped in a vise with the incision just protruding above the jaws, and given one or more shearing blows with a heavy short-handle hammer. With set-copper, one blow was sufficient to break the specimen in two; the nearer the sample approached tough-pitch copper, the larger was the number of blows required to obtain a fracture.

color has changed to a brick-red; in the apex of the depressed surface there has appeared the characteristic single bubble. Finally, Fig. 11 represents refined copper brought to wire-bar pitch; the fracture is finely-granular and fibrous, the lustre is very silky, and the color roseate.

Samples Nos. 0 to 6 of the Calumet & Hecla Co., shown in Figs. 12 to 18, begin with set-copper and end with ingot-copper. The fractures, starting from coarse-columnar and cubical (Fig. 12), lose their columnar character, remaining coarse and cubical (Fig. 13), they become coarsely radiated (Fig. 14), then the radiation assumes finer forms and granulation puts in an appearance (Fig. 15), granulation predominates over radiation (Fig. 16), both become finer (Fig. 17), until with Fig. 18 radiation has been entirely replaced by granulation. In a similar manner the lustre, from being absent with Fig. 12, becomes at first slightly silky; then silkiness increases until full silkiness is reached with Fig. 18. The dark brick-red color of Fig. 12 becomes lighter (Figs. 13, 14 and 15), rose-color begins to be seen (Figs. 15 and 16) until full rose-color is reached with Fig. 18.

The observations on the fractures are brought together in Table II.

DETERMINATION OF OXYGEN IN SAMPLES.

The oxygen of the different samples was determined by

TABLE II.—OBSERVATIONS ON FRACTURES OF SAMPLE-BUTTONS.

Properties.	BOSTON & MONTANA.			CALUMET & HECLA.						
	Samples.			Samples.						
	No. 1.	No 2.	No. 3.	No. 0.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No 6.
Texture.	Radiated, columnar.	Columnar, cubical, coarse.	Finely-granular, fibrous.	Cubical, columnar, quite coarse.	Cubical, coarse.	Radiated, coarse.	Finely-radiated, somewhat granular.	Granular to finely-radiated.	Finely-granular, with some fine radiation.	Finely-granular.
Lustre.	Dull.	Dull.	Very siky.	Dull.	Dull, with specks of silkiness.	Dull, with	increasing	silkiness.	Half dull, half silky.	Nearly full silkiness.
Color.	Dark brick.	Brick.	Rose.	Brick.	Brick.	Light brick.	Light brick.	Light brick to rose.	Light brick to rose.	Rose.

Several experiments were made to find the best light and time of exposure necessary, the position of the specimen with regard to the light, and the proper magnification to bring out the details in a photograph. A reversible-back Premo camera, 4 by 5 inches, was used with sunlight, the specimen having been placed on a white background. Exposures of 40, 80 and 160 seconds were tried, using a No. 32 diaphragm. With negatives half the size, the same size, one and one-half times and twice the size of the original, exposures of from 40 to 80 seconds gave good results. Trying back-light and side-light, it was found that the latter brought out the structure more satisfactorily than the former. A magnification of one and one-half was necessary to show clearly the details in the photograph.

As it is not easy to have constant conditions with sunlight, electric light from a sixteen-candle-power incandescent lamp was substituted and an enlarging camera of E. & N. T. Anthony used. With the light placed at about 5 inches from the specimen, so as to make an angle of 45° with the face, and using the middle diaphragm, an exposure of six minutes gave the best negative. With finely-granular fractures, filtering the light through ground glass was an improvement, but the time of exposure had to be prolonged to ten minutes; with the coarser structures, better results were obtained without the ground glass.

Figs. 9, 10 and 11 give the fractures of the Boston & Montana samples Nos. 1, 2 and 3 in one and one-half times their natural sizes. Fig. 9, cathode copper after melting and skimming, but before rabbling, has a fracture radiated and columnar, lustre is absent, the color a dark red. Fig. 10 is set-copper, the fracture has lost its radial character and has become coarse-columnar to coarse-cubical, it remains dull, the

means of Hampe's method,[4] which consists in reducing the oxide of finely-divided copper (brought to a bright red heat) in a current of hydrogen, the loss in weight giving a measure for the oxygen-content. Hampe,[5] and later Heyn,[6] gave evidence that the reduction is complete. The apparatus used and recommended by Hampe was somewhat modified, partly along the lines suggested by Archbutt[7] and partly by changes which suggested themselves during the work. On account of the smallness of the samples, it was necessary to use less material for the analyses than did Hampe, *viz.* from 10 to 13 grams. The apparatus used consisted of a 16.5-inch Kipp gas-generator (charged with hydrochloric acid and feather zinc), a gas-washing bottle filled two-thirds full with a saturated solution of caustic soda, a drying-tower with sticks of caustic soda, a U-tube filled with calcium chloride, a bulb-tube filled with copper borings and a second U-tube filled with calcium chloride.

The bulb-tube, of Bohemian glass, 3-16-inch thick, was 8 inches long, and had a bulb 3 inches long and 1.25 inches in diameter. It was supported by a frame (5 inches long by 3 inches wide, by 2.5 inches high) of "uralite" (an asbestos boarding) having slots 1.25 inches deep in the ends to receive the cylindrical ends of the bulb. The frame was placed on a thin sheet of asbestos-paper[8] resting upon a ring-stand. Under this was placed a Tirrel burner with a flame spreader.

[4] Zeitschrift für Berg-, Hütten- und Salinen- Wesen im Preussischen Staate, 1873, xxi., 231.

[5] Op. cit., p. 234.

[6] Zeitschrift des Vereins deutscher Ingenieure, 1900, xliv., 600; see also Metallographist, 1900, vi., 48.

[7] Analyst, 1900, xxv., 253.

[8] Asbestos was chosen after sheet-iron (used by Archbutt) had failed with the heating apparatus used, and coper had become oxidized and perforated too quickly.

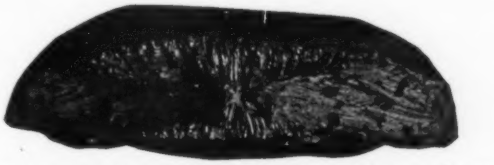


Fig. 9.—Sample No. 1, Fracture of Boston & Montana Copper. After melting, contains 3 per cent Cu_2O. (?) (Magnified 1.5 diam.)

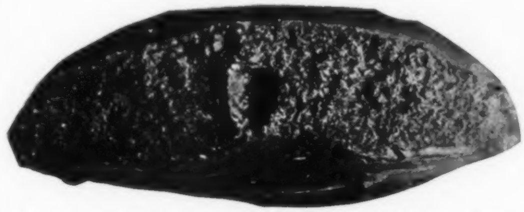


Fig. 10.—Sample No. 2, Fracture of Boston & Montana Copper. Set copper, contains 6.16 per cent Cu_2O. (Magnified 1.5 diam.)

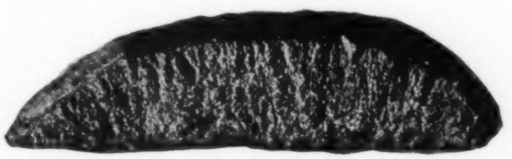


Fig. 11.—Sample No. 3, Fracture of Boston & Montana Copper. Wire-Bar, contains 0.51 per cent Cu_2O. (Magnified 1.5 diam.)

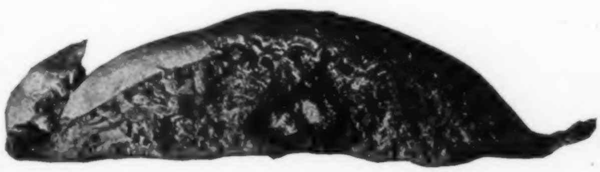


Fig. 12.—Sample No. 0, Fracture of Calumet & Hecla Copper. Set copper, contains 5.76 per cent Cu_2O. (Magnified 1.5 diam.)

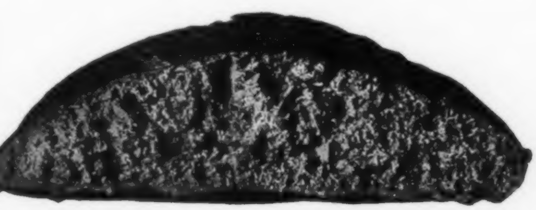


Fig. 13.—Sample No. 1, Fracture of Calumet & Hecla Copper. After poling 15 minutes, contains 6.67 per cent Cu_2O. (Magnified 1.5 diam.)

Fig. 14.—Sample No. 2, Fracture of Calumet & Hecla Copper. After poling 30 minutes, contains 3.36 per cent Cu_2O. (Magnified 1.5 diam.)

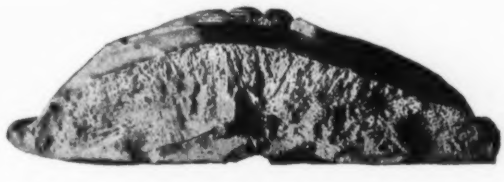


Fig. 15.—Sample No. 3, Fracture of Calumet & Hecla Copper. After poling 45 minutes, contains 1.86 per cent Cu_2O. (Magnified 1.5 diam.)

Fig. 16.—Sample No. 4, Fracture of Calumet & Hecla Copper. After poling 60 minutes, contains 1.98 per cent Cu_2O. (Magnified 1.5 diam.)

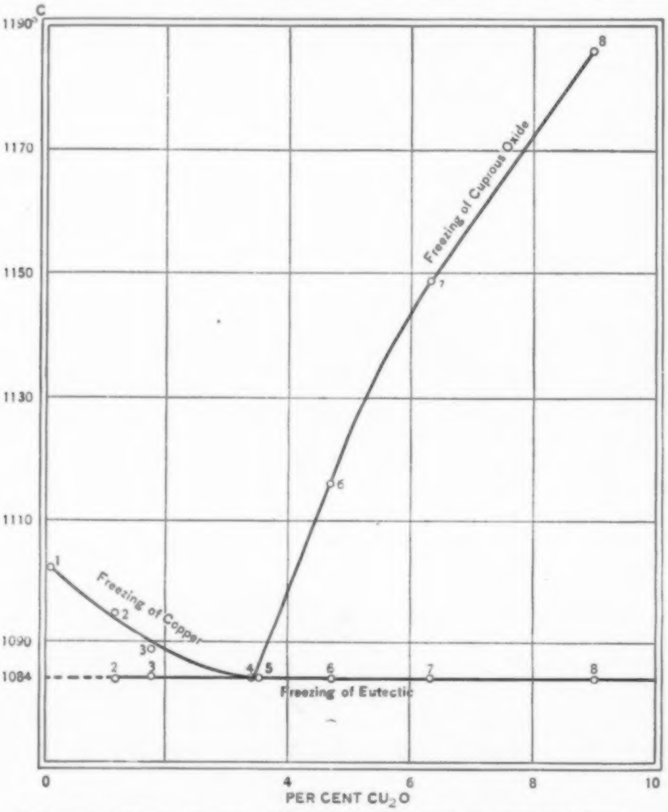
Fig. 17.—Sample No. 5, Fracture of Calumet & Hecla Copper. After poling 75 minutes, contains 0.84 per cent Cu_2O. (Magnified 1.5 diam.)

Fig. 18.—Sample No. 6, Fracture of Calumet & Hecla Copper. After poling 90 minutes (Ingot Copper), contains 0.47 per cent Cu_2O. (Magnified 1.5 diam.)

The whole was enclosed by a frame of heavy asbestos matting (7 inches long by 6 inches wide by 13 inches high) with slots in the sides to receive the protruding cylindrical ends of the bulb.

The mode of procedure was as follows: From 20 to 25 grams of borings[9] were taken for a sample, small bits of iron were removed by a magnet, the borings were washed in a beaker four or five times with alcohol and dried to remove the last traces of alcohol, care being taken to avoid any oxidation of the copper. The borings were then divided into approximately equal parts, transferred to the weighed bulb-tubes and weighed. A bulb was placed in the furnace, connected by rubber tubing with the train of hydrogen-apparatus, hydrogen passed through for five minutes at the rate of six bubbles per second, the gas issuing from the second calcium-chloride tube ignited and the bulb slowly brought to a bright-red heat. When water ceased to appear in the glass leading to the second calcium-chloride tube, the gas-current was reduced so that only three bubbles passed the wash-bottle per second, and the bulb kept at a bright-red heat for one and a half hours. At the end of this time, the supply of gas was again increased to six bubbles per second, the lamp removed and the copper allowed to cool. When cool, the bulb was disconnected, air aspirated through it, and the bulb cleaned and weighed.

The results obtained are given in Table III. It will be noticed that the average percentage of cuprous oxide of the Boston & Montana wire-bar copper is higher than that of the Calumet & Hecla cake-copper, although the former had been brought to a higher pitch and should, therefore, contain less oxygen. The discrepancy may be explained by the fact that the Boston & Montana copper contains more impurities than the Calumet & Hecla; and these impurities are present as oxides.



FREEZING-POINT CURVE OF COPPER-CUPROUS OXIDE ALLOYS.

TABLE III.—DETERMINATIONS OF OXYGEN IN SAMPLES OF COPPER.

Sample.		Weight of Copper Used.	Weight of Oxygen Found.	Quantity of Oxygen in Copper.	Quantity of Cuprous Oxide in Copper.
		Grams.	Grams.	Per Cent.	Per Cent.
Boston and Montana.	No. 1	9.9251	0.0319	0.322*	2.88 *
		10.2990	6.0347	0.337*	3.015*
	No. 2	10.1958	0.0702	0.688	6.159
		13.2269	0.0873	0.659	5.905
	No 3	6.7495	0.0054	0.056	0.503
		6.7671	0.0048	0.058	0.523
Calumet and Hecla...	No. 0	10.5543	0.0679	0.643	5.757
		11.5738	0.0744	0.643	5.755
	No. 1	12,6041	0.0791	0.628	5.618
		10,9886	0.0700	0.640	5.725
	No. 2	11,9961	0.0430	0.358	3.207
		12.1626	0.0456	0.375	3.360
	No. 3	11.8279	0.0242	0.205	1.830
		16.2051	0.3440	0.212	1.900
	No. 4	12.6454	0.2940	0.221	1.980
		13,8294	0.3080	0.223	1.990
	No. 5	18.3018	0.1250	0.094	0.841
		18.2256	0.1690	0.093	0.839
	No. 6	11.3544	0.0059	0.052	0.465
		12.2972	0.0072	0.058	0.524
		13.1625	0.0068	0.052	0.463

MICROSCOPICAL EXAMINATION OF SAMPLES.

The pieces of copper used for making microsections were sawed out as nearly as possible from the center of a fracture, as it was thought that some segregation might have taken place in the cooling. Later observations, however, showed that this precaution was unnecessary as long as the superficially oxidized surface was excluded. The samples were all finished with the polishing-machine made by the Boston Testing-Laboratories.[10] In using the machine for rough-polishing, the emery on the canvas-wheel pitted the surface to such an extent that it became necessary to file the specimen smooth before proceeding any further. In regular work, therefore, the sawed specimens were first treated with a rough, followed by a smooth file, and then polished with rouge and water on a revolving wooden disc covered with broadcloth. In polishing, considerable difficulties were encountered at first, as the polished surfaces, when examined under the microscope, showed disturbing scratches. Polishing by hand with rouge and water on a smooth board, covered first with sheet-rubber and then with chamois, gave a more lustrous surface than when the wheel was used, but at the same time it intensified the scratches. This pointed to the probable presence of coarse particles in the rouge. In order to remove them, about one volume of rouge was stirred up with two volumes of water in a beaker, allowed to settle for about 30 seconds, and the suspended matter applied with a brush to the broadcloth disc. The results were satisfactory, and all samples were treated in this manner. When polished, they were cleaned with alcohol and wiped dry with chamois. By thus applying the rouge, running of water onto the machine could be dispensed with, which made the whole operation cleaner. Experiments with decanting the suspended rouge from that which had settled, filtering and then applying the filter-contents to the disc did not work well.

In examining the polished sections with the microscope,[11] magnifications ranging from 30 to 750 diameters were tried. As a high magnification did not bring out the structure more clearly than did one of a smaller diameter, but only narrowed the field of observation, a comparatively low magnification of 100 diameters was chosen. This gave a magnification of about

[9] In boring, the drill was run very slowly to prevent the heating of the sample.

* These samples contained some sulphur, which was given off as hydrogen sulphide; the figures represent, therefore, oxygen plus sulphur, and not sulphur alone—and the figures in the last column ought to be too high, but, as seen by micrograph, Fig. 19, they are very much too low.

[10] Metallographist, 1901, iv., 275.

[11] Made by C. Reichert, Vienna (Bausch & Lomb Optical Co., Rochester, N. Y.)

230 diameters on the photographic plate. To the eye the contrast between the black[12] cuprous oxide in the eutectic (or the bluish-black excess-cuprous oxide in samples containing over 3.45 per cent Cu_2O) with the red-colored copper was clearly visible, but the photographic plate failed to show it. In order to bring out the structure more clearly, various attempts were made to etch with nitric acid, sulphuric acid, silver nitrate and with the electric current, but they did not improve matters. Heat-tinting did some good, but not enough. Yellow and orange-colored screens were then tried; of these the orange-colored glass proved to be the better, especially when a rapid isochromatic plate particularly sensitive to orange and yellow light was used for photographing. The orange light gave the copper a yellowish tint, but had little effect upon the cuprous oxide. The copper alone having an actinic effect upon the photographic plate, it appeared white in the positive, and the cuprous oxide black. The time of exposure giving the best results was found to be two and a half minutes.

The Boston & Montana sample No. 1 (Fig. 19), taken after melting and skimming the cathodes, is seen to contain a slight excess of cuprous oxide over the eutectic, although the analysis gives only 3 per cent cuprous oxide. The black crystals are small, but easily distinguished from the cuprous oxide of the eutectic. Sample No. 2 (Fig. 20), set-copper, contains a large excess of cuprous oxide over the eutectic; it shows fern-like forms which spring up in relief against the eutectic background. The fern-like forms are very unevenly distributed; the eutectic field in some places was free from them, in others

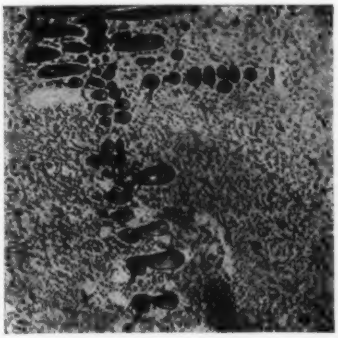


Fig. 23.—Sample No. 1, Micrograph of Calumet & Hecla Copper. After Poling 15 Minutes, contains 5.67 per cent Cu_2O (magnified 100 diam.)

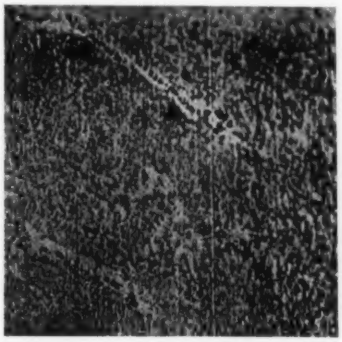


Fig. 24.—Sample No. 2, Micrograph of Calumet & Hecla Copper. After Poling 30 Minutes, contains 3.36 per cent Cu_2O (magnified 100 diam.)

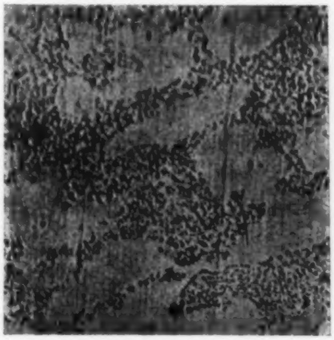


Fig. 25.—Sample No. 3, Micrograph of Calumet & Hecla Copper. After Poling 45 Minutes, contains 1.86 per cent Cu_2O (magnified 100 diam.)

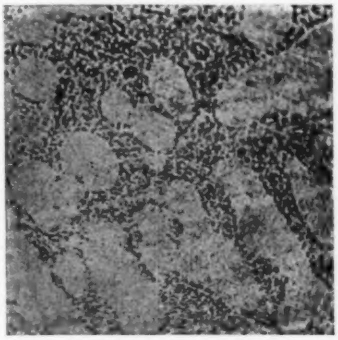


Fig. 26.—Sample No. 4, Micrograph of Calumet & Hecla Copper. After Poling 60 Minutes, contains 1.98 per cent Cu_2O (magnified 100 diam.)

Fig. 27.—Sample No. 5, Micrograph of Calumet & Hecla Copper. After Poling 75 Minutes, contains 0.84 per cent Cu_2O (magnified 100 diam.)

Fig. 28.—Sample No. 6, Micrograph of Calumet & Hecla Copper. After Poling 90 Minutes, contains 0.47 per cent Cu_2O (magnified 100 diam.) (Ingot Copper Cooled Quickly.)

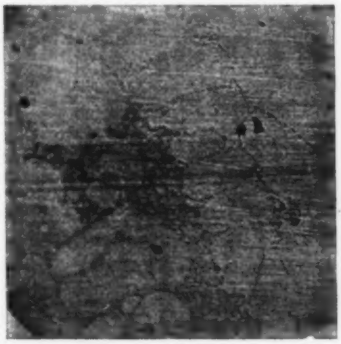


Fig. 29.—Sample "A," Micrograph of Calumet & Hecla Ingot Copper Cooled Slowly, contains 0.91 per cent Cu_2O (magnified 100 diam.)

Fig. 30.—Sample "B," Micrograph of Calumet & Hecla Wire-Bar Copper Cooled Slowly, contains 0.275 per cent Cu_2O (magnified 100 diam.)

Fig. 31.—Sample of Micrograph of Nichols & Co.'s Plate-Copper (magnified 100 diam.)

[12] To Heyn, op. cit., using chemically pure materials, it appeared bluish-black.

it was entirely covered with them. Sample No. 3 (Fig. 21), wire-bar copper, shows an evenly distributed fine network of eutectic enclosing large meshes of copper.

In the Calumet & Hecla series, sample No. 0 (Fig. 22), set-copper, shows patches of excess-cuprous oxide in the eutectic. Sample No. 1 (Fig. 23), taken fifteen minutes ofter poling had begun, does not differ much from sample No. 0, proving that the reduction had not proceeded very far. On the whole, both samples resemble very much the set-copper sample (No. 2) of the Boston & Montana, although they do not show the fern-like forms so clearly developed. The eutectic, in most cases, is slightly separated from the patches of excess-cuprous oxide crystals by a narrow band of copper, and the cuprous oxide in the eutectic seems to have separated somewhat from its copper, thus giving the field a spherulitic appearance.[13] In sample No. 2 (Fig. 24), the third taken, reduction has progressed rapidly, but it still contains a slight excess of cuprous oxide over that of the eutectic mixture. It resembles sample No. 1 of the Boston & Montana series. In sample No. 3 (Fig. 25), the eutectic has been passed, and the excess-copper becomes apparent. Sample No. 4 (Fig. 26) shows that little progress was made in the reduction in the fifteen minutes that elapsed between the taking of samples No. 3 and No. 4. An explanation for this is that during this period, forty-five minutes after poling had begun, the poles were withdrawn and new ones put in their places. In sample No. 5 (Fig. 27), the cuprous oxide is very much diminished, the eutectic forms a thin network enclosing copper in its meshes. Finally, sample No. 6 (Fig. 28) represents refined copper brought to ingot-pitch. The network of the eutectic is imperfect and broken, and the dark parts of the eutectic are bunched together and larger than expected. The explanation of this peculiar structure may be found, when Figs. 2 and 8 of Heyn's micrographs are compared, by the supposition that the sample was chilled when still above 1084° C., the melting point of the eutectic, which prevented the eutectic from separating out in the form of a continuous skeleton. In order to find out whether this idea was a correct one, a new sample (A), taken at the ingot-copper stage from another furnace-charge and cooled slowly was obtained and examined. Fig. 29 brings out clearly the difference between quick and slow cooling. Fig. 30, sample (B), represents the same batch of copper when ready to be ladled into wire-bar, the sample having been also cooled slowly. The skeleton here also is seen to be continuous and not broken, as in Fig. 28.

Finally, micrograph Fig. 31 represents a sample of copper from the Nichols Chemical Co. which has been brought to plate-pitch, *i. e.*, the poling has been carried further than is the case with the highest degree of wire-bar pitch of the Calumet & Hecla Co.

AREA-MEASUREMENTS.

Measurements of areas which gave Sauveur[14] such interesting facts seemed very promising when applied to samples of copper containing less cuprous oxide than the eutectic mixture. Measuring the copper-areas and deducting them from the total area would give the eutectic area, and from this the percentage of cuprous oxide could be readily calculated. It would be useless, if not impossible, to measure the areas of cuprous oxide in the eutectic; and on account of the unequal distribution of cuprous oxide in specimens with more cuprous oxide than the eutectic, the data would be misleading.

For the purpose of measurement, enlargements were made of sample No. 3 (wire-bar copper) from the Boston & Montana Co., of samples Nos. 3, 4, 5 and 6 (ingot-copper, chilled) from the Calumet & Hecla Co.; also of sample A (ingot-copper, cooled slowly) and sample B (wire-bar copper, cooled slowly) from the Calumet & Hecla Co.; and of the sample of plate-copper from the Nichols Chemical Co.

[13] See H. M. Howe, "Iron, Steel and Other Alloys," Boston, 1903, p. 41.

[14] Trans., xxvi., 878.

The enlargements measured 16 by 20 inches, giving five times the magnification of the micrographs, or about 1150 diameters. A circle, 12 inches in diameter, was drawn on an enlargement, divided into four quadrants, and measurements made on each. The Amsler planimeter was the instrument employed. It is commonly used for the measurement of indicator-cards, and is accurate to 0.1 per cent. The copper areas on an enlarged micrograph were outlined with a pencil in order to facilitate measurement. All measurements were carried out in duplicate. It took from 1.5 to 2 hours to measure the copper-areas of a micrograph, the time varying with the clearness with which the edges of the eutectic were defined. Thus, samples No. 5 and especially No. 6 of the Calumet & Hecla series were very difficult to measure. In calculating the percentage of cuprous oxide in the eutectic, the figure 3.45 was chosen, being the average of Heyn's two determinations, 3.4 and 3.5.

The degree of accuracy of the measurements, carried out at least in duplicate, is shown by examples in Table IV., in which A-V represent the copper-areas of one sample.

TABLE IV.—PLANIMETER MEASUREMENTS OF COPPER-AREAS.

Copper-Area.	A.	B.	C.	D.	E.	F.	G.	H.
Square inches....	2.35	1.04	1.61	2.24	0.27	10.17	2.56	8.26
	2.33	1.04	1.61	2.24	0.27	10.13	2.56	8.27
	2.35	....	....	....	....	10.14	....	....
Copper-Area.	**I.**	**J.**	**K.**	**L.**	**M.**	**N.**	**O.**	**P.**
Square inches....	0.78	2.83	7.90	4.57	3.20	5.22	3.39	3.14
	0.78	2.83	7.87	4.57	3.20	5.20	3.42	3.12
	....	....	7.86	....	....	5.20	3.40	3.12
Copper-Area.	**Q.**	**R.**	**S.**	**T.**	**U.**	**V.**	....	....
Square inches....	5.47	6.57	4.04	2.21	2.91	2.80	....	....
	5.45	6.53	4.01	2.21	2.87	2.80	....	....
	....	6.57	4.00	....	2.84	....	....	....
	....	....	....	....	2.84	....	....	....

The percentages of cuprous oxide resulting from the measurements in the several quadrants and the averages are given in Table V.

TABLE V.—PLANIMETER MEASUREMENTS OF QUADRANTS OF VARIOUS SAMPLES.

Sample.	First Quadrant.	Second Quadrant.	Third Quadrant.	Fourth Quadrant.	Average of Quadrants.
No. 3 (B. & M.)......	0.58	0.52	0.36	0.48	0.49
No. 3 (C. & H.)......	2.34	1.76	1.22	1.84	1.79
No. 4 (C. & H.)......	2.00	1.37	1.95	2.06	1.85
No. 5 (C. & H.)......	1.00	1.15	0.31	1.11	0.89
No. 6 (C. & H.)......	0.39	0.93	0.61	0.30	0.56

It will be seen that the measurements of the quadrants of a sample show some discrepanices, as the copper-islands are not uniformly distributed in the eutectic network. An excess of constituent in one quadrant is, however, balanced by a lack in another, giving on the whole a very satisfactory average.

The results obtained by fracturing and by chemical and microscopical analysis are brought together in Table VI.

The features relating to fractures have already been summarized. Comparing the cuprous-oxide content obtained by chemical analysis and by planimetric measurement, it will be seen that the percentage of cuprous oxide found by analysis in the Boston & Montana sample No. 3, and in the Calumet & Hecla samples Nos. 3 and 4, is somewhat higher than that by measurement. This may be due to the fact that the chemical analysis gives the total oxygen, that of the copper, as well as that of the impurities, while measurement gives only the oxygen of the copper. That the oxygen found by analysis in the Calumet & Hecla samples Nos. 5 and 6 is lower than that obtained by measurement is probably due to the segregation of the cuprous oxide in the eutectic, causing the latter to spread somewhat. Taking the results as a whole, they show that area-

TABLE VI.—PHYSICAL CHARACTERISTICS AND CORRESPONDING CONTENT OF CUPROUS OXIDE AND OXYGEN IN VARIOUS SAMPLES.

Mark of Sample.		Boston & Montana.			Calumet & Hecla.									Nichols Chemical Co.
		No. 1.	No. 2.	No. 3.	No. 0.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	A.	B.	
Fracture		Radiated, columnar.	Columnar, cubical, coarse.	Finely-granular, fibrous.	Columnar, cubical, coarse.	Cubical, coarse.	Radiated, coarse.	Finely-radiated, somewhat granular.	Granulated to finely-radiated.	Finely-granular, finely-radiated.	Finely-granular, finely-radiated.	Finely-granular, finely-radiated.	Finely-granular, fibrous.	Finely-granular.
Lustre		Dull.	Dull.	Very silky.	Dull.	Dull, specks of silkiness.	Dull, more silkiness.	Dull, more silkiness.	Less dull, more silkiness.	Half dull, half silky.	Nearly full silkiness.	Nearly full silkiness.	Full silkiness.	Less silky than A.
Color		Dark brick.	Brick.	Rose.	Brick.	Brick.	Light brick.	Light brick.	Light brick to rose.	Light brick to rose.	Rose.	Rose.	Rose.	Rose.
Per cent. of cuprous oxide.	by analysis	3.00	6.16	0.51	5.76	5.67	3.36	1.86	1.98	0.84	0.47	------	------	------
	by measurement.	------	------	0.49	------	------	------	1.79	1.85	0.80	0.56	0.91	0.39	0.28
Per cent. of oxygen.	by analysis	0.33	0.69	0.057	0.64	0.68	0.38	0.21	0.22	0.094	0.053	------	------	------
	by measurement.	------	------	0.055	------	------	------	0.20	0.21	0.099	0.063	0.102	0.043	0.081

measurements of enlarged micrographs of pure coppers containing less oxygen than the eutectic give good valuations of the oxygen-content. Further, it seems entirely feasible to make quickly a close estimation of the percentage of cuprous oxide contained in a sample of copper by simply examining a polished surface with the microscope, when once some experience has been gained. The mode of operating might be as follows: To take a button-sample, cool it slowly and quench it when it had solidified, cut out a piece with a circular saw, grind it smooth on a number of revolving wooden discs covered with emery-cloth or on revolving files, polish with rouge and water on a revolving disc covered with broadcloth (a mirror-like surface would not be necessary), and estimate with the microscope the percentage of cuprous oxide present. The whole operation could be done in from six to eight minutes. The poling could then be controlled by the microscope, and the degree of pitch desired for ingot-, large or small cake-, wire-bar- or electrode copper defined by a readily ascertainable amount of cuprous oxide that should be present.

In conclusion we wish to thank Professors Richards and Fay for many valuable suggestions made during the course of the investigation.

ANOTHER NEW METAL.—From a recent consular report, we quote as follows: "A new metal, which is similar to aluminium, but still of lesser weight, has been discovered by the French engineer, Albert Nodon, and called 'nodium,' after him. It is manufactured by an electric process. In color, lustre, and structure it is almost exactly like steel. Its specific weight when molten is only 2.4. Its resistance against breaking is given as about 20 pounds per square of 0.04 inch. Its constancy in the air is higher than that of aluminium. Its ductility is between 6 to 8 inches; the malleability can be compared to that of bronze. It melts at about 600°. It is suitable for being cast into forms. The conductibility for the electric current is as high as that of copper of equal weight. If natural power, especially water power, can be used for its manufacture, the cost in round figures is about 15 cents per pound. The inventor expects numerous uses of nodium in the near future, especially for electric wires and cables, for light but strong parts of motor cars, torpedo-boats, men-of-war, street cars, military outfits, air ships, etc., and for castings in place of bronze, German silver, and similar metals. Nothing definite has yet been communicated as to the chemical composition of nodium nor as to the mode of its manufacture." It would be interesting to get some more authentical information on the properties and composition of this metal.

PHILADELPHIA SECTION OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

The first meeting of this section was held in the lecture hall of the Engineers' Club, of Philadelphia, on February 5, Mr. Carl Hering being in the chair, and Mr. S. S. Sadtler acting as secretary. The attendance was comparatively small, but the discussions were quite animated, and of a high order, although they turned occasionally far away from the exact subject under consideration. The meeting, being decidedly informal, was a full success.

COMPOSITE VOLTAGE.

The first paper was presented by Prof. J. W. RICHARDS, on this subject. When a current passes through an electrolyte, a part of the energy consumed appears in the form of Joulean heat, while the balance corresponds to the energy of the electrochemical action. It is with this latter energy that the author deals. He purposely neglects any thermoelectric effect and bases his considerations simply upon Thomson's rule.

As long as there is one single electrochemical action, the energy corresponding to it is easily found from thermochemical data. If we know how many coulombs have passed through the cell (which are directly found from the quantities of substances reduced and oxidized at the two electrodes, with the aid of Faraday's law), we may divide the total energy consumed (in watt seconds or volt coulombs) by the total amount of coulombs, and then get the e. m. f. in volts which corresponds to this single electrochemical action. For instance, in copper plating with the use of a soluble copper anode, as long as we neglect the Joulean heat, and as long as the solution is throughout of uniform concentration, there is theoretically no energy required to dissolve copper at the anode, and deposit it on the cathode, hence the e. m. f. corresponding to this electrochemical action is also zero. If acidulated water is electrolyzed between platinum electrodes with a resulting evolution of hydrogen at the cathode, and oxygen at the anode, the energy of the electrochemical action is equal and opposite to the heat of the formation of water from hydrogen and oxygen. If we calculate this energy in watt seconds for that amount of water which is decomposed by one coulomb, we get the e. m. f. of the electrochemical action in volts. All this is well known.

What Dr. Richards discusses in his paper is the case that not a single electrochemical action is going on, but several different actions simultaneously. How is the voltage of the electrochemical action to be calculated in this case. For instance, in one step of the Browne process, both copper and nickel are dissolved from the copper-nickel anodes, while copper only is deposited upon the cathodes. Here we have two distinct electrochemical actions, the one being the same as in

copper plating, in so far as copper goes into the solution at the anode, and out of the solution at the cathode, while the other reaction is represented by the equation $Ni + CuCl = NiCl + Cu$. The energy corresponding to the first electrochemical action is zero, the energy corresponding to the second electrochemical action is given by thermochemical data. Now, if a certain number of coulombs pass through the cell and a certain proportion of the same dissolves copper from the anode while the balance dissolves nickel from the anode, then the energy corresponding to the electrochemical action of the first portion of coulombs is zero, while the energy of the second portion of coulombs (those which dissolve nickel) can be calculated from thermochemical data. The total energy corresponding to the electrochemical action in watt seconds is therefore equal to that consumed by the coulombs which dissolve nickel and deposit copper. If we divide this total energy in watt seconds by the total number of coulombs which were passed through the cell, we get the volts corresponding to the total electrochemical action. This is what Dr. Richards calls composite voltage, since it refers to two distinctly different electrochemical actions.

Another case of great practical importance is the simultaneous deposition of a metal with the evolution of hydrogen. In this case we have again two distinct actions and calculate the energy corresponding to each action separately. By adding them we get the total energy, and by dividing the latter by the total number of coulombs we get the voltage corresponding to the total action.

An interesting calculation which may be drawn from this theory is that the composite voltage depends, not only on the nature of the two reactions which go on simultaneously, but also upon the extent to which the one reaction prevails over the other. The generalization of the rule to more than two simultaneous electrochemical reactions is, of course, simple.

In the discussion Mr. Smith emphasized that Prof. Richards' theory seems to contradict the common assumption that a distinct voltage is required for the discharge for each kind of ion. Dr. Richards replied that this assumption is based on the supposition that only one single electrochemical action is going on, and is then a consequence of the energy principle; in the case of a mixed action one must proceed in the calculations as was shown in his paper.

Formation of Hypochlorite.

A paper on this subject was presented by Mr. S. S. Sadtler, who described experiments made by him to determine the following relations: First, the influence of alkali on the total amount of hypochlorite formed in the electrolysis of solutions of common salt; second, the influence of different concentrations of sodium chloride in the solutions; third, the influence of current density on the yield of hypochlorite; fourth, the influence of anodes of different materials on the yield of hypochlorite; fifth, the chemical action of anions on some of the anodes used.

In general it was found that very small amounts of alkali, such as one or two grams per liter, very much lessened the amount of hypochlorite formed with some concentrations of salt, and with other concentrations it prevented its formation entirely. Higher current densities favored the yield of hypochlorite and increasing amounts of salt in solution increased the yield up to a certain point, and then it fell off with stronger solutions. Peroxide of lead electrodes gave the best yield, next came platinum and iron, while nickel gave the lowest yield.

In the discussion which followed, Dr. Gahl referred the observations made with different electrode materials to the different overvoltages at the various electrodes.

Theory of Electrode Voltage.

A paper on this subject was presented by Dr. Rudolf Gahl. While the final results which he arrives at are the well-known formulas of Nernst, the method by which he reaches them is quite novel, being based on the modern theory of electrons.

Helmholtz has shown that some electrochemical processes are easy to explain if one assumes electricity as a kind of matter, and regards it as a substance composed of atoms of very small atomic weight. As Nernst explains in his "Theoretical Chemistry," the law of Faraday is thereby reduced to the chemical law that compounds are always formed in certain proportions or simple multiples of it. The recent researches on cathode rays have also shown the great fruitfulness of Helmholtz's idea. It was even possible to determine the atomic weight of the electrical atom. The successful application of the atomic theory of electricity suggests to make a further step by trying to regard the generation of the electric current in a galvanic cell in a purely chemical way.

It must be assumed that the electrons are soluble in metals, and that accordingly there is a tendency to distribute them equally in the solvent. In other words, if we apply this to solutions, osmotic pressure drives the electrons from a higher pressure to a smaller one, but in electrolytes electrons only exist bound to other atoms, in the form of ions and other molecules.

According to these ideas the dissolution of zinc in the Daniell cell is a dissociation of a Zn atom (with two positive and two negative electrons) into a Zn ion (with two positive electrons) and two negative electrons. The only difference from a common chemical dissociation is that one of the dissociation products is only soluble in one phase, the other product in the other one. Otherwise it is quite the same, as, for example, the dissociation NH_4Cl into NH_3 and HCl. In this system addition of NH_3 lowers the pressure of HCl, and addition of HCl the pressure of NH_3. In just the same way, in the other case addition of zinc ions lowers the pressure of the electrons, whereas an increase in the pressure of electrons in the metallic phase lowers the osmotic pressure of the zinc ions near the electrode. The same relations as for a common dissociation equilibrium may, therefore, be applied here. If we do not consider the variation of the equilibrium with the temperature the equation may be written:

$$p^2_{(-)1} = \frac{k_1}{p_{Zn^{\cdot\cdot}}}$$

This equation shows how the osmotic pressure of the electrons varies with the concentration of the zinc ions.

In order to build up a cell it is necessary to have two electrodes. To get a Daniell element a copper electrode in copper sulphate solution has to be used as second electrode. For the equilibrium between copper ions and electrons an equation of the same kind will exist.

$$p^2_{(-)2} = \frac{k_2}{p_{Cu^{\cdot\cdot}}}$$

If the electric current in the metallic circuit is regarded only as a movement of electrons, the direction of the current will depend on which of the $p_{(-)}$ values is the greater one. The e. m. f. is the work that can be done by the electrons falling down from the higher osmotic pressure to the lower one.

In applying the laws of dilute solutions it is found

$$E = R\,T \ln \frac{p_{(-)1}}{p_{(-)2}}$$

or if the above derived values are substituted

$$E = \frac{R\,T}{2} \left[\ln \frac{k_1}{p_{Zn^{\cdot\cdot}}} - \ln \frac{k_2}{p_{Cu^{\cdot\cdot}}} \right.$$

This is the formula which was derived by Nernst a long time ago. It is interesting that it is possible to reach the same formula by only regarding the electromotive process of a cell in a purely chemical way, and it seems to indicate that the assumption made was right, that it is allowed to make calculations with a negative electron in the same way as with any other atom. But if this is right, we have to change some of our electrochemical ideas. For example, there would be no absolute potential at all, for, as a copper ion is then a chemi-

cal compound different from metallic copper, we cannot assume that metallic copper is in equilibrium with a certain concentration of copper ions, but have also to consider the electrons, which must have a certain osmotic pressure dependent on the concentration of the copper ions to make the equilibrium complete.

APPLICATION OF THERMODYNAMICS IN THE CALCULATION OF ELECTROMOTIVE FORCE.

A brief note on the subject was presented by Mr. E. W. SMITH on the nature of the phenomena which are commonly comprised in the term overvoltage. He considers that the well-known Gibbs-Helmholtz equation takes account of the overvoltage in the second term which contains the temperature coefficient of the e. m. f.

Dr. Gahl doubted whether this conclusion is correct, since the Gibbs-Helmholtz equation is based on the assumption that the discharge or charge of a cell is absolutely reversible. The question thus resolves itself into the other one whether the evolution of gases at an electrode is absolutely reversible in thermodynamical sense. If it is then the phenomenon of the overvoltage must appear in the second term of the Gibbs-Helmholtz equation. It would be interesting to collect the experimental data relating to this question.

STRUCTURE AND TENSION.

By OSKAR NAGEL, PH. D.

It was stated in an editorial of the February issue of ELECTROCHEMICAL INDUSTRY that, regarding electrodeposition, the structure of a metal is possibly playing a more important part than its tension.

I will try to show now that the structure of a metal is dependent on the location of the metal in the tension series, and it is a matter of opinion if the one or the other is estimated as of higher importance. The "tension" is the more general expression having a wider scope, and is therefore to be preferred.

In looking over the tension series we notice that in going from silver to copper, lead, iron, zinc, aluminium and magnesium, we are going constantly from the (technically) more metallic to the less metallic metals, from the more passive to the active metals, and from metals with low dissolving tension to metals of high dissolving tension. The structure is changing accordingly.

It is known (Nernst, *Theoretische Chemie, Dritte Auflage*, page 679) that the decomposition of water by metals is increased

1. With the increasing pressure of the hydrogen ions.
2. With the increasing dissolving tension of the metal, or with decreasing osmotic counter-pressure of the ions of the metal.

Therefore, for the electrodeposition of metals out of salt solutions,

I. The concentration of the ions of the metal A has to be as high as possible, and

II. The concentration of the hydrogen ions B has to be as low as possible.

As now in water solutions the concentration of the hydrogen ions B is decreasing proportionally with the increasing concentration of the hydroxyl ions C it is necessary for the electrodeposition to have AC as large as possible. According to the law of solution this is limited by the solubility of the hydroxide of the metals. The impossibility of electrodepositing aluminium or magnesium out of water solutions is therefore explicable, not only by the high dissolving tension of these metals, but also by the exceedingly low solubility of their hydroxides.

As the conditions I. and II. are getting more and more unfavorable in going from silver to magnesium, the difficulty of electrodeposition is increasing accordingly.

THE THEORY OF ELECTRODE POTENTIAL.

By WOOLSEY MCA. JOHNSON.

In preceding articles (ELECTROCHEMICAL INDUSTRY, vol. I., 1903, pp. 373, 454, 537) we endeavored to give some account of the experimental facts of electrode potential, to show what it was, how it could be measured, and the standards against which it was measured. This article concludes the series by developing the theory along two lines, viz.:

(1) Thermodynamics.
(2) Osmotic Pressure.

Heretofore we aimed at novelty of treatment and illustration. Now, we will follow quite closely the lectures given by Prof. W. Nernst in the years 1899-1900.

The theory of electrode potential developed along the lines of thermodynamics is independent of any special theory or hypothesis which describes the supposed mechanism of the energy changes. It is immaterial whether the energy takes the form of osmotic energy or of "solution energy." The laws of thermodynamics hold good whatever the mediums be.

It has been aptly said, that thermodynamics is "energy-book-keeping." We measure first how much energy a system had. Next we measure how much energy was added to the system, how much energy it gave up in form of useful work, how much energy it gave up in useless heat in the operation. Finally, we measure the energy at the end of operation. By equating these with the proper signs, the sum is equal to zero. In reality thermodynamical calculations resemble an "energy-balance-sheet."

The first law of energy is expressed indefinitely in the above paragraph. Exactly it can be stated as follows. The decrease in total energy is equal to the work done by the system, less the heat supplied the system from the outside surroundings, or

(1) $U = A - Q$,

where U = decrease in total energy
A = work done by system
Q = heat given to system.

As a corollary to this law, which is a mathematical statement of the law of the conservation of energy, we have the law that there is always a constant relation between different forms of energy, as thermal, electrical, mechanical. For instance, we know by experiment that 772 foot-lbs. = one British thermal unit.

The gist of the second law of thermodynamics is that "a person cannot lift himself by his boot-straps." More exactly, the maximum amount of useful work any system can perform depends on two factors, and is mathematically expressed by the equation,

$$(2) \quad dA = Q \frac{dT}{T}$$

Any process by which the work is done in accordance with the above formula is styled a "reversible" process. The maximum amount of work is done when a "reversible" process is carried on.

A third law is a combination of the first two.

$$(3) \quad A - U = T \frac{dA}{dT}.$$

for by (1) $A - U = Q$, and by (2) $Q = T \frac{dA}{dT}$

We will now assume in the electrochemical system anode-anolyte-catholyte-cathode, that all the potential energy of chemical separation is changed into electrical energy when the cell is closed through an outside resistance. For purposes of calculation, the Daniell cell will be taken as it is the classical example. This special assumption is called "Thomson's rule," for it was first made by Sir William Thomson, now Lord Kelvin. It is not exactly correct, but still in many cases gives remarkably close approximations.

The e. m. f. of a Daniell cell varies with the concentration. For convenience in calculation we will take it as 1.10 volts. Let us connect it with an outside resistance of 1.10 ohms. On closing the circuit, by Ohm's law, exactly one ampere will flow, if the resistance of the cell is zero. If the resistance of the cell be made very small, say 0.005 ohms, by constructing a cell of 200 times the electrode area of the usual cell, the loss in internal resistance can be neglected.

If the current flow for one day, the energy absorbed by external circuit is given by the equation,

$$A = E \times C \times 24 = 1.10 \times 1.00 \times 24 = 26.4 \text{ watt hours.}$$

Now measurements of the relation between electrical energy and heat have been very carefully made by Prof. Rowland and others. For purposes of this calculation, the value 1 watt hour = 0.87 kilogram calorie is sufficiently accurate. This means that a 50-watt incandescent lamp will raise one liter of water (which weighs nearly a kilogram) 43.5°C. in one hour, if the water surrounds the lamp and is protected from radiation by mineral wool or asbestos, so that no heat is lost by radiation.

Consequently the heat developed by the Daniell cell in 24 hours is,

$$A = 26.4 \times 0.87 = 23.0 \text{ calories.}$$

Twenty-three calories is enough heat to raise 1 kilogram of water 23° C. Therefore, if we had a Daniell cell as large as a wash-tub whose resistance would be negligible with leads of No. 12 wire running through a beaker of water, containing one liter of water, we might expect that the water would become hotter at the rate $\frac{23}{24}$ ° C. per hour, provided our assumptions are true and no heat is lost by radiation.

Now, Faraday's law demands that in the 24 hours one ampere will dissolve a definite amount of zinc and precipitate a definite amount of copper. Foster's Handbook gives the values for one ampere hour 1.1855 grams copper, and 1.2193 grams zinc. Taking these values as 1.19 and 1.22, which is accurate enough for this calculation, we have in our 24 hours' run, deposited 28.6 grams of copper, and dissolved 29.3 grams of zinc.

Chemistry teaches that 65.5 grams of zinc will precipitate 63.0 grams of copper out of a copper sulphate solution with the evolution of 50.13 calories of heat. The reaction proceeds very energetically with zinc dust and is quantitative. As a matter of fact it is a reaction often made use of in analytic determinations of copper. Julius Thomsen, the great Danish thermochemist, determined this by the difference of the reactions,

$$Zn + O + SO_3 = 106.090 \text{ calories.}$$
$$Cu + O + SO_3 = 55.960 \text{ "}$$
$$\overline{\quad 50.130 \text{ calories.}}$$

It can be parenthetically remarked that Thomsen was extremely practical in his ideas. His design of furnace for calcining cryolite is in use to-day in this country.

In our Daniell cell we have 29.3 grams of zinc dissolved instead of 65.5, consequently the heat evolved in the beaker of water, our rough calorimeter, is

$$A = \frac{29.3}{65.5} \times 50.13 = 22.4 \text{ calories.}$$

We had calculated from the electrical equivalent of heat, and the e. m. f. of the Daniell cell 23.0 calories. Considering the limits of error in the measurement and remembering that the Daniell cell has a different e. m. f. for different solutions, varying from 1.08 to 1.11, the agreement is surprisingly close.

However, refinements in measurement can be made and the solutions made so that they represent the actual solutions used by Thomsen in his thermochemical experiments, the value of e. m. f. is then 1.093 volts, corresponding to 25.263 calories,* while the reaction gives only 25.055 calories. The difference is 0.208 calorie.

*Nernst, Theoretische Chemis., p. 650.

With other cells this difference is much larger and can even amount to 30 or 40 per cent instead of less than one. So we see that Thomsen's rule is only an approximation, and that there must be some other factor in the equation which does not enter into the equation.

It was deduced by von Helmholtz and W. Gibbs that Thomsen's rule only held when the e. m. f. of the element varied but little with the temperature. A fixed relation between the temperature-coefficient of the e. m. f. of the cell and the discrepancy from Thomsen's law was deduced theoretically. This has also been proven experimentally. Cells which give a higher e. m. f. than Thomsen's rule calls for have a positive temperature coefficient, while those that have a lower e. m. f. have a negative e. m. f. The former absorbed heat from the surroundings in electrolysis, while the latter evolved heat. Obviously this change is comparable in a rough way to heat absorbed when ice is melted or water is boiled.

This relation is the law known as the Gibbs-Helmholtz equation.

$$A - U = T\frac{dA}{dT}$$

The relation can be worked out for the special case of the Daniell cell. Heat of chemical change less external work = — H (H being amount of heat the system exchanges with the surroundings.)

$$Q - E = - H.$$

Let us take a Daniell cell at a temperature T and discharge it until one coulomb of electricity has passed through it. The electrical work done is E joules. The reaction heat is Q. The temperature is now raised to T + dT, and the cell charged with an outside source of electricity dissolving copper and precipitating zinc, the e. m. f. at temperature T + d T being E + dE. When one coulomb has passed, the electrical work done is E + dE joules. Allowing the cell to cool to T we have everything in condition to start.

We have then, by the second law of thermodynamics,

$$dE = H\frac{dT}{T} = (E - Q)\frac{dT}{T}, \text{ or } E - Q = T\frac{dE}{dT}$$

Applying this equation (the Gibbs-Helmholtz equation) to the Daniell cell, we have,

$$E = 25.263 \text{ calories corresponding to } 1.093 \text{ volts.}$$
$$Q = 25.055 \text{ calories, Thomsen's value.}$$
$$E - Q = 0.208 \text{ calories.}$$
$$T = 273^\circ$$
$$\frac{dE}{dT} = 0.000034 \text{ volts (found by experiment).}$$
$$E - Q = 0.000034 \times 23.110 \times 273.214 \text{ calories.}$$

This agrees very closely with value 0.208 calorie, obtained by the other calculation. Numerous other cells have been tested and their e. m. fs. found to agree very closely with that calculated by Gibbs-Helmhotz equation.

As remarked in the opening of this article, the theormodynamical theory is general. It does not explain the mechanism. It simply analyses the energy changes. The osmotic dissociation theory does more than this. It gives an account of the means by which these changes take place.

The osmotic theory assumes that a dissolved substance behaves exactly as if it were a gas, and the solvent a vacuum. The osmotice pressure is found to follow the law $P = \frac{RT}{V}$.

When sugar dissolves in water there must be some pressure which drives the sugar molecules in solution. This is called "solution-pressure." The osmotic pressure opposes this solution pressure. This pressure is due to an attraction between the solute and solvent. Dissolved substances lower the freezing point and raise the boiling point, according to definite

laws. These laws state that equivalent molecular parts will produce the same effect in lowering freezing point, etc.

Now, when the formulas found otherwise to be true for lowering freezing point, and raising the boiling point, are applied to solutions of such salts as sodium chloride, it is found that in each case the laws only hold good unless we assume that the number of molecules have been increased in some way.

This discrepancy shows remarkable similarity with discrepancies in the measurements of the vapor density of ammonium chloride. On volatilizing this salt the pressure noted is much larger than that deduced from the laws of Boyle, Charles and Avogadro. This leads to the deduction the ammonium chloride is broken up into its constituents ammonia and hydrochloric acid, thus

$$NH_4Cl = NH_3 + HCl.$$

For an extended account of the experimental facts and deduction from them, the reader is referred to Jones' "Elements of Physical Chemistry," p. 60 et seq. The dissociation is caused by heat.

Analogously, it is taken that sodium chloride in aqueous solution is broken up into a sodium ion and a chlorine ion, the charge of electricity modifying their chemical properties. The equation in this case is

$$NaCl = Na^{\cdot} + Cl'$$

This reaction is not complete, but becomes more complete as the dilution increases. At infinite dilution it is theoretically complete. The electrolytic dissociation is caused by the high dielectric constant of water.

Of a 100 molecules of sodium chloride dissolved in water we will say that 50 are dissociated and 50 undissociated. The total number of particles exciting pressure is now 150, because the basis of the whole theory is the assumption that an ion exerts just as much pressure as an undissociated molecule.

Each ion, however, can carry just so much electricity depending on its chemical valence, and each ion offers a certain amount of friction depending on its nature to the solution. It may be said that each ion has a specific carrying capacity for electricity. Thus, the electrical conductivity is proportional to the sum of free ions in the solution.

From the electrical conductivity of solutions the number of dissociated molecules can be calculated. For further details of this, including Kohlrausch's law, etc., the reader is referred to the "Theory of Electrolytic Dissociation," by Jones. Suffice it to say that there is a very close agreement between the different dissociation constants calculated from the electrolytic conductivity, freezing-point method, boiling-point method, and osmotic pressure.

Now we will return to electrode potential. To account for any material movement we must have recourse to the conception of pressure. The pressure which causes water to change into vapor is termed vapor-pressure. That which causes sugar to dissolve in water is termed solution pressure. Accordingly, the pressure which causes zinc to dissolve as anode is termed electrolytic solution pressure. There is always an electrical displacement along with the material displacement.

The nature of electrolytic displacement is essentially different from electrical displacement in a metal wire. In the latter case the "electrons" are moved from molecule to molecule without any movement of what is denominated "sensible matter." In the former case matter actually moves with the "electrons."

The following analogy was told me by Mr. William Stanley some twelve years ago, and has been, on many occasions, a great help in giving a concrete conception of the difference between the two kinds of electro-conduction.

In metallic conduction the electrons are passed along, as coal would be passed along a line of men with shovels. The men with shovels are the molecules of metal. In electrolytic conduction each man has a wheel-barrow of the same capacity, or an even multiple thereof if he is stronger. The coal is actually pushed along in these wheel-barrows.

Similarly each ion can carry 96,540 coulombs of positive or negative electricity, or an even multiple thereof. In a preceding paragraph, it was noted that each ion had its own specific constant of electrical conductivity, the sums of which for all anions and all cations was the conductivity of the solution. These constants for ions are intimately connected with the so-called "transport numbers" (a rendering into English of the word Ueberführungszahl).

If finely divided chalk is suspended in a tall jar of water, the particles will fall slowly to the bottom. The motion is slow and takes place at a definite velocity if the particles be of the same size. The "damping" effect of the water is so great that the velocity does not increase, but is practically constant. Like conditions hold in the pull of the field of electrostatic stress between two electrodes on the charged ions. This stress would pull them through at an increasing rate if they were free to move. But the electrolyte offers so great friction to the movement, that the displacement is directly proportional to the time. There are very few analogies more complete than that between the falling of finely divided particles through a medium offering great friction and the flow of cations to cathode and anions to anode.

The above is but a brief epitome of the theory of electrolytic conduction. It is impossible within the limits of this article to do more than to explain the facts of the previous articles in the light of the dissociation theory.

The electrolytic solution pressure of any metal is termed P. The non-metals, oxygen, chlorine, bromine, etc., have also an electrolytic solution pressure tending to make them anions. In the case of metals with a high solution pressure, a certain amount of atoms are thrown off from the metal into the electrolyte, carrying a certain charge. This leaves metal negatively charged. The process continues until the attraction between the negatively charged metal and positively charged solution is so great that just as many ions jump back to the metal as are thrown out from the metal. The so-called "double-layer" is now in a state of equilibrium. However, if there is a zinc electrode, and the electrolyte originally had possessed zinc ions, it is clear that the equilibrium would be reached much quicker, because there is already a pressure on the double layer tending to deposit ions on the metal. This pressure is due to the osmotic pressure of the ions, and is written p. In any electrolysis we are thus carrying metallic ions from a pressure P to a pressure p, or the reverse if the metal is deposited.

The laws of gaseous pressure hold for osmotic pressure, and we are really distilling matter from one pressure P to a pressure p. The laws of gas-pressure are contained in equation $pv = RT$. Mechanics teach that the work (A) done in passing matter at constant temperature from one pressure to another is thus given by

$$A = \frac{RT}{c} \ln \frac{P}{p}.$$

In the previous articles we noted the experimental fact that metallic electrolysis was reversible at small current densities. This work (A) is the maximum amount of work that can be done from the pressure P to pressure p provided the process is reversible and temperature constant.

When we allow the electrolysis to continue until one coulomb has passed from cathode to catholyte the work done is expressed by a general equation:

$$A = E\,C\,T$$

Where A = watt seconds or joules.

E = e. m. f. in volts.

C = current in ampere.

T = time in seconds.

As CT is equal to unity, we have simply: $A = E$, then as A from first equation $= \frac{RT}{c} \ln \frac{P}{p}$, we get

$$E = \frac{RT}{c} \ln \frac{P}{p},$$

Where R = gas constant.

T = absolute temperature.

C = number of coulombs to deposit one gram of hydrogen (96.540)

changing to Brigg's logarithus and putting in values for

$$R, T, C, E = 0.0577 \log. \frac{P}{p}.$$

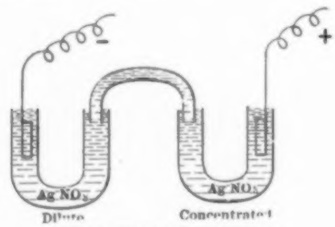
We now have an exact expression for the electrode potential of any metal dipping in a solution of its salts. It may be objected that this looks very pretty in theory, but cannot be proven. It was put to the test of experimental proof about fifteen years ago by Prof. Nernst, by a very simple experiment.

For the same metal P is a constant. Balancing one solution pressure against another, we have,

$$E_1 - E_2 = 0.0577 \log. \frac{P}{p_1} - 0.0577 \log. \frac{P}{p_2},$$

$$\text{or } e = 0.058 \log. \frac{P_2}{p_1}.$$

This formula is the formula for the e. m. f. of a so-called concentration cell.



CONCENTRATION CELL.

Two strips of silver dip into a solution of silver nitrate of different concentrations in two U-tubes. The two U-tubes are connected with a siphon of solution. Solution in I. is dilute, in II. concentrated. The concentrations should be so selected that the ions are ten times as numerous in the concentrated solution as in the dilute. Thus, the pressure of II. is ten times as great as that of I. We have seen that the osmotic pressure opposing the electrolysis depends on the ions and not the undissociated molecules. The logarithm of ten is 1. Consequently, if we neglect the e. m. f. at the meeting of the two solutions, $e = 0.0577$. The value found was close to this value. Making all corrections, the error was as small as could be expected. Decreasing the concentration in I., until the ratio is 100, we find the experimental value to be close to 0.116 volt.

So having found that the e. m. f. is a measure of the concentration of ions by the logarithmic ratio of the pressures (concentration being proportional to pressure) it is possible to measure the concentration of the silver ions of unknown silver solution if we measure the e. m. f. against a standard silver electrode.

For example, the combination,

Ag, AgCl, $AgNO_3$.1N, Ag
nKCl

gave 0.51 volt. Therefore, $C_2 = 1.10 \times 10^{-10}$.

Direct measurement by chemical analysis gave 1.21×10^{-10}. The following† will explain some of the facts about concentration cells.

We know, for example, that it is possible to reverse a Daniell cell by simply adding a strong solution of KCN to the catholyte; that this will give a steady discharge of a considerable current, with the copper dissolving and the zinc being precipitated.

† Electrochemical Industry, February, 1903, p. 212.

By Nernst's equation we have

$$E = e_1 - e_2 = 0.058 \log. \frac{Pzn}{pzn} - 0.058 \log. \frac{Pcu}{pcu}$$

neglecting the small e. m. f. at the contact of the solutions.

Now, when we add KCN to catholyte, we do not affect Pzn or pzn or Pcu, but we reduce Pcu to a small value. In other words, we have decreased the ionic pressure of copper to an amount so small that its own solution pressure is sufficient to push the copper ions continually into solution. Copper hydrate is, for analytical purposes, considered insoluble, but the solution pressure of $Cu(OH)_2$ with regard to the copper ions is large compared to that of the potassium copper-cyanide that is formed.

Similarly, we find that in a "concentration cell" that reagent which produces a chemical action in precipitating a dissolved salt or in dissolving a precipitate gives a higher e. m. f. against the standard electrode.

To be concrete, the cell

Ag|$AgNO_3$0.1n|AgClnKCl|Ag gave 0.54 volt.
Ag|$AgNO_3$0.1n|$AgNO_3$nNH_4OH|Ag gave 0.54 volt.
Ag|$AgNO_3$0.1n|AgBrnKBr|Ag gave 0.64 volt.
Ag|$AgNO_3$0.1n|$AgNO_3Na_2S_2O_3$|Ag gave 0.84 volt.
Ag|$AgNO_3$0.1n|AgIKI|Ag gave 0.91 volt.
Ag|$AgNO_3$0.1n|$AgNO_3$KCN|Ag gave 1.31 volt.
Ag|$AgNO_3$0.1n|$AgNO_3Na_2S$|Ag gave 1.36 volt.

We can see that each reagent in the electrochemical series produces a chemical action on the compound just below it. For instance, AgCl is soluble in NH_4OH, while AgBr is precipitated by the action of KBr on the soluble ammoniacal silver salt. The same is seen through the series $Na_2S_2O_3$, KI, KCN, Na_2S. This knowledge throws a Nernst light on the subject. We find in the ionic theory of concentration cells a satisfactory explanation for the perfect correspondence between chemical behavior and the electrochemical quantity, e. m. f. against a standard electrode. The same correspondence is found true in most concentration cells measured. For further particulars, the reader is referred to Nernst's classical researches on concentration cells, in the *Zeit. f. Phys. Chemie.*, 1889, to Le Blanc's "Elements of Electrochemistry" (translated by W. R. Whitney), p. 178.

It is therefore quite easy to understand why NH_4OH dissolves AgCl, etc. It is that a double salt is formed by the two, which has such a small pressure of silver ions that the reaction proceeds until equilibrium is reached. Looked at broadly, it is little different from the rising of heated air or the flowing of water down hill. All three actions consist in matter flowing from high pressure to low pressure. The difference lies in us. Water pressure and air pressure are familiar to our minds, but ionic pressure is a new conception.

Now, if we could determine the equilibrium point of the reaction, $Zn + CuSO_4$ $ZnSO_4 + Cu$ by analytical data we could determine the e. m. f. of the Daniell cell by the equation

$$E = 0.057 \log. K$$

where K equals the equilibrium constant of the law of mass action.

This is exactly the same as former equation for e. m. f. of Daniell cell, if

$$K = \frac{c_1 c_2}{c_3 c_4}.$$

Still one more phenomenon of electrode potential can be noted. This is the fact that with only very few electrodes is the decomposition of an electrolyte with formation of gas a reversible process. There is always a certain excess of potential with electrodes that exhibit the Casparian "overvoltage." This voltage is effective in making reductions at the cathode and oxidations at the anode. For organic electrochemical methods it has been especially valuable.

In starting these articles on electrode-potential, which is one of the most important divisions of electrochemistry, it had been

the original intention to extend the series over the entire subject and to give such conceptions of the experimental facts which had been found useful in practical work. The aim was to serve the maximum number of readers, chemists, electrochemists and electrical engineers. It is to the regret of the writer that other work has a greater "electrode-potential" than this, with the resultant displacement of the weaker. Needless to say, the crystallizing of these articles were a source of benefit and pleasure, even though done in odd moments of a busy year. It is hoped that the readers have likewise shared in this benefit.

THE CYANIDE PLANT AND PRACTICE AT THE YMIR MILL.

In a paper presented to the American Institute of Mining Engineers, Mr. EDWIN C. HOLDEN gives a very interesting account of the cyanide plant and practice at the Ymir Mine, West Kootenay, B. C. Some results obtained by the author in his previous investigation of the situation, and some features of the practice, adopted at his advice, are quite novel.

The vanner-tailings during the quarter ending January, 1903 (and all the figures here given, unless otherwise stated, are for that period), assayed 0.0882 ounce gold and 1.051 ounces silver per ton; lead, 1.3; and zinc, 2.2 per cent. Of this material, 65 per cent would pass a 100-mesh screen.

The vanner-tailings being of comparatively low grade, Mr. Holden felt himself practically confined to the adoption of the system of direct filling and percolation; and, as slimes-treatment was not at the same time to be provided for, the object was to treat as large a proportion of the slimes as possible with the sands; or, in other words, to make charges having the lowest practicable rate of percolation. This minimum rate is usually stated as 2 inches per hour.

It is also a current conception that a much larger proportion of slimes can be handled in an intermediately-settled charge than in a directly-filled one. To determine whether this possible difference in tonnage was important enough to justify the increased cost of installation and operation of a plant with settling-vats was an important problem, which was decided in an experimental plant, consisting of two 35-ton leachers, 5 ft. deep. One leacher was charged direct from a Butters' distributor, which was fed by the bottom-discharge of a pointed box carrying the vanner-tailings from twenty stamps. The box got rid of excess water and a little of the finest slimes. The second leacher was charged from a two-compartment box in which the vanner-tailings were settled, the sands being dropped from the compartments alternately as filled, and shoveled in the leacher as in ordinary intermediate filling-plants.

The results were rather unexpected, it being found that direct filling, when properly done, not only leaves a charge in as good condition for treatment as the intermediate method, but renders it possible to treat a larger proportion of the slimes. It is suggested as an explanation that in a charge settled under water the grains of sand are free to arrange themselves most compactly, with a minimum of voids, and the slimes are held near where they originally settled, because the interstitial currents are not marked enough to disturb them; whereas, in charges shoveled into a vat with less than 15 per cent of moisture, the voids are a maximum, and the slimes which originally coated each grain of sand are washed off and settle through the charge, and, thus segregating, prevent uniform percolation. The fact that direct-filled charges never pack or settle more than 1 per cent, while indirect ones frequently contract over 10 per cent, during treatment, tends to confirm this view.

The final plant is located half a mile from the stamp mill and 300 feet vertically below it. The vanner-tailings are carried to the plant by a box-launder 6 by 8 inches in section, and the excess of battery- and vanner-waters allows of a minimum grade of slightly under 5 per cent. At that grade, and with 1-inch riffles set 5 inches apart in the bottom of the box, the durability even of the local soft hemlock and cedar lumber used is quite satisfactory.

To make the required fall of 300 feet to the plant, a series of drop-boxes is inserted where the topography is favorable; and a 12-inch sand-pocket at the bottom of each drop, to prevent wear, should also be an efficient saver of escaping amalgam or mercury.

The tailings enter the top of the storage-solution room; and when, as in the period under consideration, from forty to sixty stamps are running, the classification is done in two boxes, the first being 18 by 24 inches wide by 18 inches deep, with two vertical sides and false ends sloping 60° to a 0.5- by 24-inch slot, under which hydraulic currents can be applied. This box settles only the coarse sands, which are drawn off through a 2-inch nipple into the charging launder. The second box is pointed, 3 feet 6 inches in width and depth, and 7 feet long, with a 3-inch outlet. A plug-valve in this outlet, in combination with the hydraulic current in the box, regulates the speed of the distributors, while maintaining the same separating action in the box. The overflow from this box, carrying about 60 per cent of the water and 20 per cent of the total tailings, is run to waste. This overflow should all pass a 100-mesh screen, and is mostly impalpable material.

All of the vats and tanks, except the sumps, are of steel. The leachers, 32 feet in diameter by 6 feet deep, are on timber foundations with masonry footings. Caps and sills are parallel, an arrangement which renders jacking-up easier than the usual right-angled structure. Bents and posts are spaced 4 feet between centers, and the bracing does not extend above the post, the shimming being done between posts and caps. On the caps are 4- by 8-inch joists spaced 18 inches between centers. There is no flooring on any of the vat- or tank-joists, and there is headroom under them all, so that leakages occurring in the plant cannot be unknown or inaccessible. The vats are fitted with top annular-overflow launders; and, to preserve a level rim, a soft wood strip, projecting above the edge of the vat, is fastened with stove-bolts to the side-plates, the joint being calked with oakum. Any settling of the vats which is insufficient to require jacking-up from below can thus be easily rectified, just as with tongue-topped wooden vats.

The distributors are of the usual type, and have twenty 1.5-inch arms. This area of discharge-openings, with our quantity of tailings, never allowing any head to accumulate in the distributor-hopper, renders uniform distribution difficult. The slightest throw of the stream from the charging drop-box off the center of the hopper results in uneven charging, most of the slimes going to the low side of the vat. Many devices were tried to remedy this, and to prevent twisting of the drop-stream, which motion also has a classifying effect; and the last and simplest plan was successful. The drop was made square; and inside the lower end of it an iron strip was fastened to each side. The square drop prevents twisting, and to throw the stream toward the low side of the charge small wedges were driven under the iron strips, as needed.

These details may seem trifling; but when the object is to treat the maximum quantity of slimes by percolation they will be found of prime importance in obtaining a uniform charge.

Where there is enough headroom to give distributor-arms 3-inch grade per foot, arms of 1-inch diameter, or even smaller, could be used without danger of clogging. This would be an improvement upon the usual form, which has 1.5-inch arms at 1.5-inch grade; for it would approach the ideal conditions requiring a maximum number of arms fed from a full hopper.

Continuous, uniform charging is essential to make a good charge; hence, so far as possible, stamp-mill hang-ups were made between charges. When, however, an emergency hang-up was made with a charge incomplete, a gentle hydraulic current was started under the filter in the vat; the water-feed to the distributor was increased; and, when charging was recom-

menced, the settlers were run with a strong hydraulic current for a few minutes, allowing only the coarse sands to settle. Despite every precaution, however, a slime-layer will mark in the charge every mill hang-up of over ten minutes' duration.

The classification of values in charges and overflows was marked, the average assays and screen-tests for the year being:

	Au. Oz. Per Ton.	Ag. Oz. Per Ton.	Through 100-Mesh. Per Cent.
Vanner-tails	0.0838	1.008	64.86
Charges	0.0931	0.637	50.70
Overflows	0.0621	1.878	98.90

The high silver in the overflow is due to its association with galena in the slimes.

The system of classification was crude; and if the plant were pushed to its full capacity, close hydraulic classification, yielding a clean, quick-percolating charge, would be necessary; but, as run at this time, the system was very satisfactory, for it settled and treated a total of 70.1 per cent of the vanner-tailings. When they were treating oxidized ore, charges could not be successfully treated that carried over 45 per cent of fines.

With all the stamps dropping, a vat was filled in from twenty-eight to thirty-two hours; but during the last quarter of 1902 it required from forty-eight to sixty hours. The experimental work called for five days' treatment; but, with the reduced crushing, they increased the proportion of slimes settled, and treated charges as long as our capacity allowed,—the average time of treatment being 10.5 days. A normal charge was 185 tons, dry weight.

The acid tests seem, in the case of the Ymir tailings, to be worthless as an indicator for the use of lime. The ordinary tests for latent acidity called for over one pound of lime per ton. Phenolphthalein indicated more. They used 200 pounds to the charge for a while, until the zinc boxes grew so foul that dried precipitates assayed under 1200 ounces of total fine bullion per ton. The methyl-orange indicator was more satisfactory. It called for less than 0.5 pound of lime per ton. But the final practice, which gave the best results, was to use less than 0.1 pound per ton, and apply it in 5-pound lots, the last lot going on with the final dose of strong solution. The cyanide-consumption was thus reduced over 10 per cent; and the zinc-box crude precipitates rose in grade to over 5300 ounces per ton. In treatment, the final filtrates became very cloudy when they titrated between 0.1 and 0.05 per cent KCN; and the small addition of lime, just before starting weak treatment, tended to keep the slimes coagulated and the filtrates clearer.

Vacuum percolation was soon discarded, as it gave a very dirty filtrate and packed the charges, so that the final rate of percolation was slower, even with the vacuum, than it would have been if unassisted throughout.

The routine of treatment was as follows:

After leveling and adding dry lime, two 5-ton doses of weak solution (between 0.1 and 0.05 per cent KCN) are successively given. When these have disappeared they are followed by four or five 10-ton doses of strong solution (0.2 per cent) at five-hour intervals. There is no trace of cyanide in the filtrate for six hours after the first application of weak solution, and there are no values until after fifteen hours. After 40 or 50 tons of strong treatment the charge is drained six hours, when the filtrate has almost ceased, and titrates 0.04 to 0.07 per cent KCN. Twenty tons of strong solution are now run in under the filter. It requires from six to eight hours to run this in without channeling the charge, and when it is all in, if drainage has been sufficient, there will not be more than 5 inches of solution on top of the charge. After soaking from three to six hours, the charge is drained, and a 10-ton top treatment follows. Top and bottom treatments thus alternate until 160 tons of strong solution have been applied. Then follows weak treatment, applied on top in 5-ton doses as rapidly as it disappears, to a total of 40 or 50 tons. This is followed by wash-solution (0.05 per cent to trace KCN), 40 tons; and this, by water as required, to preserve the balance of solutions or secure low end-filtrates. No solution is run to waste, other than what is lost as moisture in the residues.

The adoption of bottom-treatment had a marked effect. During the first six months' operating, when only top-treatment was used, the gold-extraction gradually fell off from 70 to less than 50 per cent; and assays from the bottom of the charges were discouraging. When the connections for bottom-treatment were made in October, the gold-extraction rose at once from 48 per cent in September, to 75 for October; and the average actual gold-recovery for the last quarter of the year was 80.23 per cent, while the actual silver-recovery also rose from 25 to 41 per cent.

The total time of treatment was from 9.5 to 11.5 days. The average rate of percolation was 1 inch per hour, although 64 and 71 per cent gold extraction were obtained from charges having only 0.5-inch and 0.6-inch rates. The highest rate during this period was 1.5 inches per hour. This slow percolation means high cyanide consumption and long treatment; but it also means larger slimes-tonnage treated. It does not require a large increase in daily tonnage to pay for extra vats and a little more cyanide.

Residues are discharged through two 10-inch plug flanges placed 4 feet from the sides of the vats. A 2.5-inch hose with 2-inch nozzle is used under 115 pounds pressure, the hose being held in a swivel-clamp at the edge of the vat. The bottom 6 inches is cleaned out at reduced pressure. One man will sluice out a charge and clean the filter in from 3.5 to 4 hours.

The filter is three thicknesses of 16-ounce burlap, having the usual false bottom and rope-grouting, and anchored to the vat-bottom to counteract its buoyancy.

Precipitation is effected by zinc shavings in eight ten-compartment steel boxes, and it is perfect with the weakest solutions when run at the rate of one ton of solution per twenty-four hours per cubic foot of shavings. The shavings in the wash solution-box are lead-dipped. Whenever there were values in the effluent, running at the normal rate, they were found to be due to precipitate mechanically carried over after dressing boxes, and it was found best not to disturb a box after it had been running more than a week, but to add shavings on top as required.

The clean-up method, while it just about competed with refiners' rates, was not satisfactory. The precipitate was dried, fluxed and smelted direct, without either acid or roasting treatment, and without refining, which produced a bullion of 720 total fineness. The treatment-loss was 1 per cent of the gold and 0.5 per cent of the silver. The clean-up cost, including freight and treatment of the resulting high-grade zinc-slag, was 17 cents per pound of dried slimes. This does not include charges for bullion shipment.

Operating costs per ton in detail for the last quarter, when 7150 tons were treated, were as follows:

Cost of Treatment per Ton

Cyanide, at $0.22 per pound	$0.200
Zinc, at $0.09 per pound	0.020
Lime, at $0.009 per pound	0.001
Fuel, at $2.50 per cord	0.019
Clean-up supplies	0.029
Repairs	0.014
Miscellaneous	0.003
Labor (wages at $3.50 and $4.50 per day).	0.234
Total	$0.520

Assay-office costs were not allocated; but the cyanide-plant proportion should approximate $0.025 per ton. These results were obtained when treating but 78 tons per day. The author states that this cost can be reduced to 38.6 cents when the plant is treating its full-rated capacity of 200 tons per day; and the introduction of reverberatory and cupel furnaces for clean-up would still further reduce it.

PIONEERS OF ELECTROCHEMISTRY.—VII.

THOMAS A. EDISON.

Thomas Alva Edison was born on February 11, 1847, at Milan, Ohio. His fifty-seventh birthday, and at the same time the twenty-fifth anniversary of the practical perfection and commercial introduction of the incandescent lamp by Edison, was celebrated by a most notable dinner of the American Institute of Electrical Engineers at the Waldorf-Astoria. In one of the speeches Mr. S. Insull expressed the conviction that posterity will not adjudge us of undue enthusiasm if we name Edison as the greatest electrochemical experimenter and the first electric light engineer of his day.

Mr. Edison's life and work is too well known to need recording here. But it seems that in view of the overwhelming results of his gigantic work in electric lighting and in general electrical engineering, it is mostly overlooked that Mr. Edison is one of the strongest and most successful representatives of industrial and applied chemistry and electrochemistry of to-day.

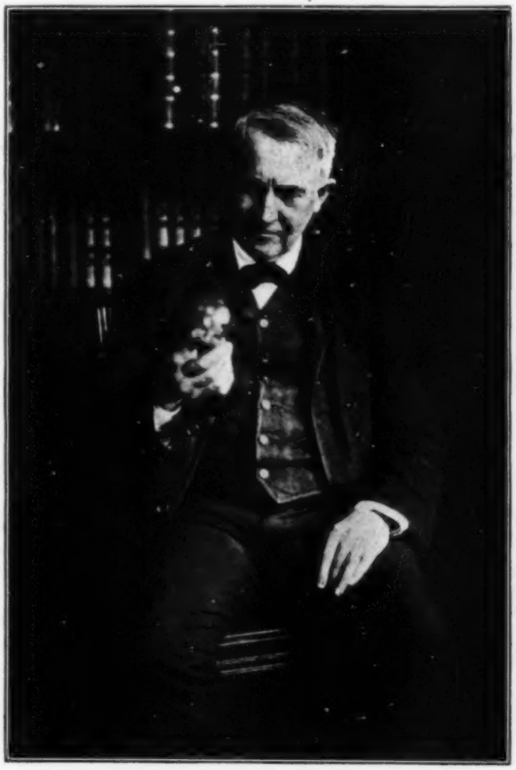
In developing the incandescent lamp, Mr. Edison was a chemist. The preparation of the filament involved difficulties which were of a distinctly chemical nature. In this connection we may mention that it is surely not incidental that the Nernst lamp, the osmium lamp and the incandescent gas light were invented by distinguished representatives of electro chemistry and chemistry; the recent achievements in arc lighting with impregnated carbons are also due to chemical research. The development of a new illuminant always requires a chemical mind, and Thomas A. Edison did here the most important and most decisive pioneer work.

While electrical engineering quickly grew so enormously that specialization soon followed and electrical engineers became either dynamo designers or lighting engineers or tramway engineers, etc., Mr. Edison always remained broad-minded, never losing sight of the whole. This explains why he was so successful in so many fields.

One of his earliest applications of electrochemistry to electrical engineering was the design of electrochemical meters in various forms for measuring ampere hours; this is, of course, a direct application of Faraday's law to the purpose of general electrical engineering.

For a long series of years Mr. Edison has been interested in the application of electromagnetism for the concentration of ores, *i. e.*, in the design of magnetic separators.

The most intimate connection of Mr. Edison with electrochemistry is, however, in the battery field. The old Edison-Lelande cell is witness of his early interest in the battery problem, and when in recent years with the boom of automobilism the inherent advantages of electric automobiles, and the inherent disadvantages of the lead storage battery for this purpose became obvious, Mr. Edison quickly attacked the problem of designing a light accumulator battery and solved it. A remark which he is quoted to have made is characteristic of him; it is to the effect that if Nature had intended lead to be used for an automobile battery, lead would not have the weight it has.



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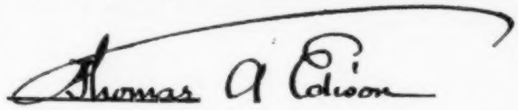


Mr. Edison, however, not only intended to produce a light battery, but one which is absolutely fool-proof. The mechanical perfection of his battery is denied by nobody, but the immense work he has done to make it chemically perfect, is probably not generally recognized.

His method of research in this special case has been the same as in all his former work to try everything, and keep the best. Mr. Edison knew exactly what he wanted: active materials which may be easily oxidized and reduced by electrolysis, and which, in all states of oxidation, are absolutely insoluble in potassium or sodium hydroxide. Mr. Edison tried the whole series of available metals, and all available methods of preparing the active material. The patents which were taken out by him, and which were duly recorded in our columns, tell only a small portion of his work, but his iron-nickel cell tells his success. The care taken by him to get pure materials is astonishing.

The fact that Mr. Edison has finally succeeded in making the steel containers for his battery in a perfectly satisfactory manner by electrolytic deposition upon a suitable mould, is another pretty example of his experimental skill in electrochemistry. Mr. Edison told the writer the other day that at the start the task seemed almost hopeless, but he kept on trying, since he was convinced that all such problems can be solved by systematic and persevering work. It is a favorite saying of Mr. Edison that inspiration, in the main, is only another way of spelling "perspiration."

Mr. Edison is of a very generous and kind nature and extremely modest; he never made a speech, never read a paper before a society, never published a book on his work. In personal intercourse, however, he is full of life and nerve and wit, and while, in speaking of paper patents, he may get quite sarcastic, his conversation is generally characterized by a very good-natured humor.

What every American engineer, and really every American feels for Mr. Edison, was admirably put into words by Mr. T. C. Martin as toastmaster at the Institute dinner: "Let us and let our sons recall and applaud the cheery little newsboy at Detroit; the half-shod, half-frozen operator seeking bravely a job along the icy pikes of the Central States; the gaunt, untutored experimenter in Boston, taking eagerly needed fees for lectures he was too modest to deliver; the embryonic inventor in New York, grubstaked by a famous Wall Street man for his first stock ticker; the deaf investigator at Menlo Park who wreaked unique retaliation on his affliction by preserving human speech forever with his phonograph; the prolific patentee who kept the pathway to the Patent Office hot with his footsteps for nearly forty years; the genius, our comrade, who took this little crystal bulb in his Promethean hand and with it helped to give to the world a glorious new light which never was before on land or sea—Thomas Alva Edison."

THE POWER PLANT OF THE MOCTEZUMA COPPER COMPANY AT NACOZARI, SONORA, MEXICO.

In nearly all the electrochemical processes, be they electrolytic or electrothermic or a combination of both, the cost of power is a large fraction of the total cost. This is well emphasized by the fact that the bulk of the electrochemical industries of this country settled down where cheap water power was available, at Niagara Falls. The same fact is also indicated by the increasing interest with which electrometallurgists follow at present all new developments in the use of the waste gases from blast furnaces for operating gas engines. Cheap power is indeed in most cases the fundamental supposition of the economical operation.

On the other hand, it is not to be overlooked that cheap power is not everything. The availability of the raw materials at the place of manufacture, and the possibility of easy shipment of the manufactured goods are also important. The question which kind of power to choose, therefore, depends to a large extent on local conditions.

An interesting, and, in several respects, quite novel gas engine-driven electric power plant is that of the Moctezuma Copper Co., at Nacozari, Sonora, Mexico. From a paper of Mr. JOHN LANGTON, presented before the *American Institute of Mining Engineers,* we gather the following information:

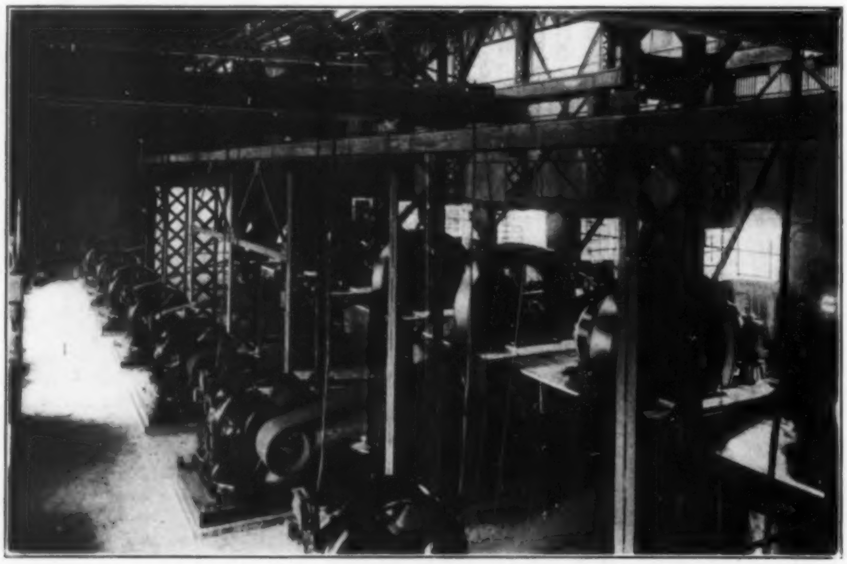


FIG. 1.—POWER PLANT OF THE MOCTEZUMA COPPER COMPANY.

The power house, the interior of which is shown in Fig 1, contains eight single cylinder Crossley gas engines, 18.5 inches diameter by 24-inch stroke, running at 200 r. p. m. These engines are of the four-cycle type, with "hit and miss" governor. Each engine is direct-belted to a 65-kw. direct-currrent generator. The generators are run in parallel, and deliver to the main switchboard in the power house, from which the current is distributed at 250 volts to some 40 different motors scattered about the works, ranging in size from 5 hp. to 175 hp. Arc and incandescent lights are operated from the same circuit as the motors.

The engines are started by compressed air, a method which has been found very simple and convenient. The cock opening and shutting off the admission of compressed air to the engine cylinder is worked by hand. Frequently but one impulse with compressed air is needed, and seldom more than three.

The gas producers are those of the Loomis-Pettibone Gas Machinery Co., arranged as shown in Fig. 2. The draught through the producers is created by the suction of the gas-exhauster, and air enters through the open feed-doors in the top of the producers. Through the same doors the fuel is charged by hand. The air thus comes into contact first with the fresh fuel, and the products of combustion, together with any distillates from the fresh fuel, are drawn downwards through the deep charge of incandescent fuel and out through the fire-brick grate at the bottom of the producer. The high temperature of the gas drawn out of the producer is partially utilized to generate steam in the boiler, through which the gas next passes, and from which it emerges cooled to about the ordinary temperature of chimney gases. It is further cooled to about atmospheric temperature in passing through the water-sprayed coke-filled trays of the scrubber, from which it finally reaches the exhauster which delivers it into the holders.

The quantity of gas made is controlled by the speed of the exhauster, which is of the positive type. The vacuum on the suction side of the exhauster, required to produce the necessary draught, depends upon the condition of the fires and the quantity of gas being made, but ordinarily it is from 12 to 24 inches of water. The exhauster delivers against the 6 inches of water pressure to which the gas holders are weighted. The total difference of pressure, therefore, is from 11 to 18 ounces.

The steam raised in the boiler is used intermittently to make water gas. For this purpose the feed-doors E and F are closed, and also the valve B. Steam is then admitted under the grate of producer No. 2, and is dissociated at the temperature of the fire, forming water gas in its passage up through producer No. 2, across the top connecting-pipe to producer No. 1, down through the latter, and out by valve A to to the boiler, the scrubber and the gas-holder. The next time water gas is made the direction is reversed; the valve A is closed, and the gas-run is made up through producer No. 1 and down through No. 2. Or, when the half the run is made up producer No. 1, steam may be shut off while valves A and B are reversed, and the other half of the run made up producer No. 2. The latter plan is generally followed at Nacozari, where the method adopted for making gas requires only short and infrequent runs of water gas.

A gas holder of 15,000 cubic feet capacity receives the gas which is to be used in the engines, and gives the necessary elastic storage between the production in the gas house and the consumption in the power house. A second gas holder of 5000 cubic feet capacity is used to receive, and to keep separate, the water gas made by the intermittent runs. By means of valves X, Y and Z, the gas is delivered to either of the holders, or is allowed to escape into the air through the purge pipe.

The producers have 6 feet 9 inches inside diameter; and when charged with coal to the highest level practicable they hold a fuel-charge 8 feet deep. A generating set consists of two producers and one boiler. At Nacozari there are two generating sets which deliver to a common scrubber and a common exhauster, with space provided for the addition of a second scrubber and a second exhauster if desired in the future. The sets are alternated in use. One is run till the accumulation of ash or clinker begins to limit its capacity; the other set is then fired, and blown to incandescence by a centrifugal exhaust fan. The valve connecting the new set to the scrubber and exhauster is opened, and the valve connecting the old set is closed. Tnere is no interruption to the

process of gas making. By means of the cleaning doors at the grate level, the producers of the old set are then emptied, and cleaned of ash and clinker. The cleaning doors are closed and sealed air-tight, and the producers charged with fuel ready to fire up again when their turn comes. The length of run on one set depends on the rate of gas making and on the percentage of ash in the fuel. At the rate of gas production required for an average load of 600 brake-hp., about 80 tons of the ordinary western coal, or about the same weight of wood, may be gasified before the accumulation of ash and clinker necessitates cleaning.

The water used in the scrubber is caught in a lower tank, and pumped back over a small cooling tower to the head tank supplying the scrubber. The feed-water for the boiler is drawn from the supply already purified by soda treatment for use in the engine jackets.

The plant has been operated with wood and with coal, both anthracite and bituminous. The down-draught principle of the producers, by which all gases pass out through the bottom of the fire, has proved thoroughly efficacious in producing fixed gases from all kinds of fuel used at Nacozari. The water from the scrubber rarely shows even that trace of tar which manifests itself by an iridescent film on the surface of the water in the lower scrubber tank.

A considerable quantity of very finely divided carbon is carried through the scrubber and into the holder and mains. It is unnoticeable at the engine valves, but it gradually deposits in the gas mains, which must occasionally be flushed out. An efficient dry scrubber to prevent its passage would be an improvement.

With fuel delivered in the gas-house bins, the attendance required is one gas maker and one helper on each shift, and extra labor for cleaning the producers.

METHOD OF MAKING GAS.

In the Loomis-Pettibone producers, as ordinarily used with the object of making as much water gas as possible, the aim is to get the fires very hot before making water gas, and to continue the admission of steam until the fires are cooled to a point where a considerable portion of the steam passes through unaltered; the making of producer-gas with air is then resumed with the aim of quickly blowing the fires as hot as possible, preparatory to steaming them again to make water gas. This procedure necessarily causes great variation in the temperature of the fires, and this, though it has little effect on the quality of the water gas, has a very great effect on the quality of the producer gas, since the latter when made by blowing a cold fire, has a large percentage of CO_2 and is lean in the combustible CO; while with a hot fire, the percentage of CO_2 is very much less, and that of CO more than correspondingly increased—one volume of CO_2 being converted into two volumes of CO.

The original intention was to make producer gas and water gas at Nacozari in the usual manner by alternate blowing and steaming, the two kinds of gas to be delivered into two separate holders, and from these drawn in definite proportions through a mixing-valve into the gas main leading to the engines. But since, in this plant, only one set of producers is available, the quality of the mixed gas would have been too variable. The method of gas making was therefore modified to avoid great variations in the temperature of the fires. The steam-pipe connections, marked M in Fig. 2, permit the introduction of steam together with the air to the top of the fire, and by this means the excess heat of the fire caused by the air-blowing may be concurrently used to make water gas; so that by properly proportioning the quantities of steam and air introduced, the fires may be maintained at a practically uniform temperature for a long period of time. The practice is to admit somewhat less top steam than could be used, in order to allow the fire to increase slowly in temperature; and then, without allowing the temperature to become excessive, to make a short water gas run which only slightly cools the fire, and to resume immediately the making of mixed gas with top steam. By this method the fire is never allowed to become cold enough to make an undue proportion of CO_2, and its maximum and minimum temperatures vary but slightly from an average high temperature.

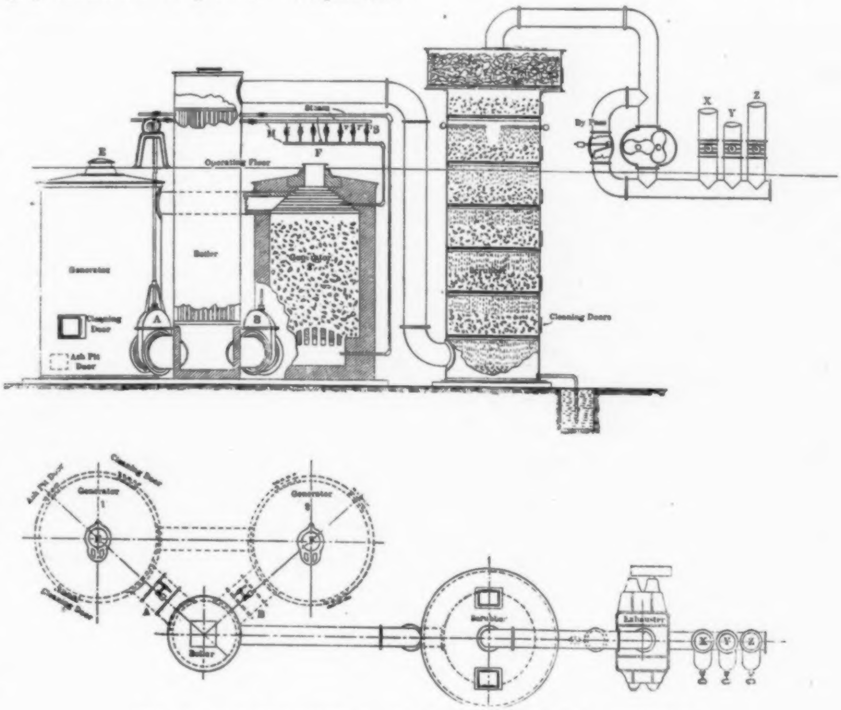


FIG. 2.—GAS PRODUCERS, MOCTEZUMA COPPER COMPANY.

The water gas made separately by this method and delivered into the water-gas holder is gradually fed from the latter into the main holder which supplies the gas engines, the water-gas holder being weighted to give an inch or two greater pressure than that of the main holder. The rate of feed is controlled by a throttle-valve, in a pipe connecting the two holders, which the operator manipulates so that the rate of feeding water gas approximately equals the rate of its production. No particular accuracy is required, nor are pains taken to regulate the quantity of water gas made separately. The operator is governed principally by the temperature of the fire, as indicated by its appearance and by the rise of steam pressure in the boiler.

The regulating cocks, marked S in Fig. 2, are drilled with small holes, and the quantity of the top steam is regulated by the number of cocks open. This gives a graduated regulation and the ability to duplicate conditions exactly. The quantity of air is independently controlled by the speed of the exhauster, or by slightly opening, to a graduated extent, the by-pass valve of the exhauster.

Gas Made From Wood.

The most novel feature of the Nacozari power plant is the use of producer gas made from wood alone, which is comparatively inexpensive in the neighborhood. The most obvious difficulty to be feared arose from the large proportion of condensible distillates yielded by wood, and the danger that some portion of these might be imperfectly fixed in passing through the producer. The trouble from tar deposited in the gas apparatus and pipes would be serious, and even a small quantity of tar in the gas itself is a fertile source of trouble at the engine valves. Unless a permanent gas could be made from wood, this fuel would be unavailable.

The first care, therefore, was to insure that there should be a bed of charcoal on the grate sufficient to form an adequate fixing zone. Although in a first trial charcoal in sufficient quantity proved effective in fixing all of the gases, it was felt, rightly or wrongly, that coke would be a stouter and more reliable screen than the comparatively frail charcoal; and in particular, that, as a reinforcement to the charcoal formed above it by the action of the fire, it would effectually safeguard against the possible danger that temporary holes might be burned through the charcoal, by which tar vapors might escape from the producer, but for the fixing-action of the more enduring coke. However correct this opinion might be, a coke-bed would certainly be an additional precaution against the serious trouble which might result from delivering imperfectly fixed gases to the holder, and would give to the operator great relief from anxiety on this score. It was therefore thought best without further experiment to use coke, which was available at Nacozari; and the practice has been continued ever since. The experience at Nacozari, therefore, does not determine whether it would be safe to dispense with the use of coke.

The wood used is principally scrub white oak, with about 10 per cent ash. The quantity of moisture contained in it varies between about 10 and 25 per cent, and is in the average 20 per cent.

Quality of Gas Produced.

The composition of producer gas made from bituminous coal is practically the same as that made from anthracite coal, but differs radically from gas made from wood; the calorific power of all three gases, however, remains constant. The type composition of coal gas and wood gas is given as follows:

Components.	Coal-Gas.	Wood-Gas.
	Volume Per Cent.	Volume Per Cent.
CO	20.0	14.0
H	14 0	20.0
CH_4	2.0	2.0
$C_n H_{2n}$	0.2	0.2
CO_2	8.2	16 0
O	0.1	0.1
N	55.5	47.7
Total	100.0	100.0
Calorific value per cu. ft., cal-cul't'd at sea level and at 60 F	B. T. U. 132.	B. T. U. 132.

As compared with coal gas, the proportions of CO and H in wood gas are reversed, and the percentage of CO_2 is doubled. With the typical compositions given above the wood gas shows less tendency than the coal gas to pre-ignition in the engines. This effect appears to be due to the large proportion of CO_2, but the reason why this is so is not apparent. Other experience at Nacozari has certainly shown a very marked tendency to pre-ignition in the engines when the gas was approximately of the following composition by volume per cent:

CO, 14; H, 20; CH_4, 2; C_nH_{2n}, 0.2; CO_2, 8.2; O, 0.1; and N, 55.5; total, 100.

The calorific value of this gas was 132 B. T. U., and yet it had the same ratio of incombustibles to combustibles, and the same composition of the latter, as the cool-working wood gas. The only difference is in the composition of the incombustibles; and it is very obscure why a change in the relative proportions of CO_2 and N should produce such markedly different results in the behavior of the engines.

The Use of Gas Engines.

Mr. Langton's paper is concluded by some interesting general remarks on the use of gas engines. The sustained capacity and satisfactory working of a gas engine depend on its being kept in thoroughly good condition. The principal meaning of "good condition" is, that the valves should seat freely, and be tight when seated; and that the inside of the cylinder should not be foul with carbonized oil.

The rated capacity of a steam engine being approximately at that point of cut-off where it uses steam most economically, there is always available a considerable reserve capacity, at the expense of economy, by admitting steam for nearly full stroke. The most economical capacity of a gas engine is its absolute maximum capacity, when at every admission it takes the maximum quantity of mixture, in the best proportions of air and gas, and ignites it at exactly the right point. The adjustments necessary to obtain all these conditions with certainty at every stroke, are too fine for any but test conditions. To allow for variations, which are inevitable, even under the best conditions in commercial working, the maximum capacity should be discounted about 15 per cent to get a figure which may be called "maximum commercial capacity;" and nothing more than this latter figure should be counted upon for those short periods which occur, even with the most uniform load, when the load rises to a maximum greater than the average. In other words, this commercial maximum capacity should equal the peak of the load curve. With a very variable load, therefore, an engine-capacity is required greatly in excess of the average power demand; and any method of averaging the power variations of individual loads by driving several such loads from one group of engines will reduce the total engine-capacity to be installed. The central power house plan with electrical distribution, is, therefore, one which is well worthy of careful consideration for at least some portion of any gas-power plant, in spite of the heavy tax to be paid in transformation and transmission losses, losses in the electric generator, the line and the motor, which practically amount to 25 per cent of the brake horse power delivered by the engines.

The ease with which gas may be transmitted to scattered points without loss, and the heavy power loss involved in transforming and transmitting the power by electric distribution, at first sight makes it appear as though the advantages of using scattered gas engines, directly connected to the shafting, would far outweigh any benefits obtainable by electric distribution from gas engines concentrated in a power house. But when the peculiarities of the engines themselves are considered, in many, not to say most cases, the balance of advantage is found to be on the side of electrical distribution, notwithstanding the cost of electrical apparatus and the constant electrical loss of 25 per cent of the power delivered by the engines.

Manganese Industry in the Caucasus.—Government statistics relating to the manganese industry in the Caucasus during 1901 have just been published as noticed in a recent consular report. In regard to the production of manganese, the first place belongs to Russia, which yields more than half the world's product. Layers of manganese exist in the Perm, Orenburg, Ekaterinoslav, and Kutais (Caucasus) Provinces. The latter are the richest, occupying an area of 54.7 square miles. The amount of manganese exported in 1901 was 355,545 metric tons, against 461,125 tons in 1900. The chief importers were: Great Britain and Holland, consuming 36 per cent and 29 per cent, respectively, of the total amount exported; next came the United States, with 14 per cent; Belgium, with 4.5 per cent; Germany, with 4 per cent; and France, with 2.5 per cent. Russia consumed only 8.5 per cent of its total yield.

NOTES ON THE LIMITATIONS OF THE CYANIDE PROCESS*

By H. T. Durant.

Speaking very generally it may be stated that it has almost become an axiom that the surface equipment of a gold or gold-silver mine is not complete without a cyanide plant.

This is no doubt, in part, due to the success attending the Witwatersrand plants, and these have been extensively copied in various places, where sometimes at least local conditions and the varying natures of the ores hardly permit such, or any, cyanide plants to be profitable.

It may be very broadly stated that ores which are amenable to any method of cyanide treatment fall naturally into two classes:

(1) Those in which the gold is carried mainly in the mineralized portion of the ore.

(2) Those in which the gold is carried free in quartz or other gangue.

The first class includes all ores in which payable values are carried in iron, copper or arsenical pyrites, tellurides, etc., or the oxidization products of one or more of these minerals, and this class permits of a wide range of treatment, varying according to special circumstances. There may also be ores intermediate between these two classes, such as the Witwatersrand ores. It is, however, principally with ores of the second class that the few remarks in these notes deal.

There are, in Rhodesia, several properties in which the ore is a fairly clean quartz, very slightly mineralized, the mineralized portion being poor in values and representing considerably less than 1 per cent by weight of the ore.

Such ores, when milled, yield values to the plates which are proportional to the fineness of the product from the mill.

If the gold in the ore is fairly coarse, the values in the mill tailings are usually such that, after milling with, say, a 700 screen apparently the mill tailings might at first sight be neglected as regards further treatment, at least on small propositions.

On the other hand, if the gold is very fine, even by increasing the battery screen up to even 1600, the tailings will still be found to be a valuable asset.

But whatever values may be in the tailings, it is found that the values extracted by cyanide are such as would in all cases entail an unsatisfactory residue, and in most cases would mean that the cyanide plant would be run at a very small profit, and this would be especially the case on small properties, where the working expenses per ton would naturally be relatively high.

There is fairly conclusive evidence that the unsatisfactory extractions by cyanide mentioned above are due to the fact that the major portion of the gold passing the plates is locked up in the gangue, and therefore not accessible to cyanide solutions, or conversely that when the ore is crushed fine enough to expose or free the gold that very nearly all the values are caught on the plates; in other words such ores are free milling propositions in the fullest sense of the term.

Table I. shows the results of actual work at the mill of the Guinea Fowl mine; these results were obtained, for confirmatory purposes, soon after the starting of the mill, practically identical results having been obtained experimentally before the starting of the mill.

The tailings under consideration in Table I., when assayed as a whole, were found to carry 4 dwts. of fine gold per ton (short).

It is seen that while slightly over 4 dwts. of fine gold are in each ton of tailings that 3.195 dwts., or nearly 80 per cent of the total values, are carried in less than 35 per cent of the total tonnage.

In other words, it is in this case merely necessary to take out by any simple sizing arrangement that portion of the tailings which fails to pass a 6,400 square measure screen, and one will then have obtained from each 100 tons of 4-dwt. tailings 34.5 tons of tailings, going 9.2 dwts. fine gold per ton, leaving 65.5 tons of tailings carrying 1.5 dwts. gold per ton, and these are more or less valueless according to local conditions.

TABLE I.

WET CLASSIFICATION OF TAILINGS FROM GUINEA FOWL MILL.

Size of material	Percentage.	Assay value dwts. fine gold per ton.	Representing dwts. fine gold per ton of tailings.
Staying on 3,600 screen (square measure)	22.5	11.00	2.475
Passing 3,600 screen (square measure), staying on 6,400 screen (square measure)	12.0	6.00	.720
Passing 6,400 screen (square measure)	65.5	1.50	.982
Assay value of tailings by calculation from constituents			4.177 dwts.

Table II. shows wet classification of tailings from another mill. The tailings, though very low in value, still well illustrate the values of the various sizes in the mill product:

TABLE II.

Size and description of material.	Percentage.	Assay value dwts fine gold per ton.	Representing dwts. fine gold per ton of tailings.
Finer concentrates panned from portion of tailings passing 2,500 screen (square measure)	4.13	4.00	.165
Coarse sand (including coarser concentrates) staying on 2,500 screen (square measure)	25.90	2.80	.725
Fine sands and slimes passing 2,500 screen (square measure)	69.80	.85	.594
Experimental error	.17		
Assay value of tailings by calculation from constituents			1.484 dwts.

Notes on Table II.—These tailings, assaying practically 1.50 dwts. fine gold per ton, are seen to carry .89 dwts. or 60 per cent of their total values in 30 per cent of their total tonnage; that is to say, that every 100 tons of 1.5 dwts. tailings will yield 30 tons tailings, assaying slightly less than 3 dwts. per ton.

It has been stated before that the total tailings mentioned either in Table I. or Table II., or any of the constituents of either tailings, yield unsatisfactory extraction by cyanide, similarly it has been proved that any of the constituents on crushing finer, yield to plate amalgamation, and also to cyanide solutions, gold in proportion to the fineness of the crushing.

In the case of tailings mentioned in Table II. it is clear that it would be good procedure to mill with a coarser screen, so that, while increasing the stamp duty, the oversize taken out from the tailings for recrushing and further amalgamation should be of a higher gold value.

The writer is acquainted with at least one case in which fine crushing of the whole ore followed by amalgamation yields exactly the same results, as regards recovery of gold, as coarser crushing with amalgamation followed by cyanide plant for the sands; in such case it is merely a question of capital expenditure and total working costs to determine which method to adopt; on the other hand, in the case of ores mentioned in

* A paper presented to the Chemical, Metallurgical and Mining Society of South Africa.

preceding tables there could be no question of cyanide plant unless after fine crushing it were cheaper to treat by cyanide than to run over plates.

Instances of this kind could, if necessary, be multiplied. It would appear that when an ore, after crushing and amalgamation yields slimes which do not pay to treat, it is good practice to increase the percentage of these slimes as much as possible while still keeping the value of the slimes below the paying point; such procedure is corelated to the well-known milling practice of California and Gilpin County.

Without intending to discuss in these few notes the question of milling in its most modern aspects, it may be taken for granted, that any exceptionally fine crushing would not usually be carried out in a stamp battery.

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl, Ph. D.

Electric Furnaces and Furnace Products.

Method of Making Carbon Articles.—E. G. Acheson, Niagara Falls. Patent 749,418, January 12, 1904. Application filed September 4, 1902.

Mr. Acheson discloses a process for making carbon articles of a high density and conductivity, by heating them up in an electric furnace, without reaching the point of graphitization. Articles thus heated increase in density from 2 to 2.13, while their conductivity is increased from 100 to 200 per cent, and the loss, which they suffer when used as anodes in an electrolytic bath, is considerably reduced. The articles are embedded in a resistance material, the specified resistance of which is greater than that of the articles. It is not intended to produce heat in the carbon articles as a result of the passage of the current through them, but to heat up the resistance material, the heat of which is then transmitted to the carbon articles which are placed in the furnace in a direction approximately at right angles to its longest dimension. A furnace which has been successfully used for this purpose is approximately 30 feet long, 30 inches wide, and 10 inches deep, inside measurements. It is constructed of ordinary bricks, but in some cases it is provided with a refractory lining of carbide of silicon. The resistance material is granular carbon, a mixture of granular carbon and silica or other metallic oxide, metallic powder or any other material conforming to the conditions stated above. A layer of the resistance material is placed on the bottom of the furnace and then the carbon articles are arranged on it, with their longest dimensions at approximately right angles to a line joining the furnace terminals. The space left between the articles is varied with the dimensions of the articles to be treated, good results being obtained with a space representing 20 per cent of the width of the carbon articles. The space between the articles is then filled with the resistance material, and layer after layer built up in the same manner. After the furnace has been filled, the top is covered with a layer of refractory and high resistance material for the purpose of excluding the air. If the articles to be treated have received already a previous baking, and are therefore conductors, they are superimposed upon each other directly, without any intervening horizontal layers of resistance material. In a furnace of the dimensions given above, good results have been obtained with 200 volts and 3750 amperes at the beginning, the volts gradually decreasing and the amperage increasing, until, at the close of the operation, after fifteen hours run, the e. m. f. was 87 volts, with a current of 8580 amperes.

Process of Electrically Heating Materials.—Alfred H. Cowles, Cleveland, Ohio. Patent 750,095, January 19, 1904. Application filed November 5, 1902.

The process consists in the use as a heating means of a resistance conductor placed in proximity to the materials to be heated, the current density being increased and the temperature thus raised continuously along the path which the material travels. The process is specifically intended for the manufacture of calcium carbide. A form of apparatus in which it may be carried out is illustrated in Fig. 1. The apparatus comprises an inverted conical stack, having an iron shell 3, a lining of refractory material 4 and a water jacket 5. The hearth is of carbon, inclosed in a casing 6, which is connected with one terminal of a source of current. A tapping hole 7 is also provided. The top is closed by a plate 8 of carbon surrounded by a casing 9. Below the massive carbon is arranged a carbon ring 21, surrounded by a water jacket 22.

FIG. 1.—COWLES FURNACE.

The cover forms the other electrode of the apparatus, and is insulated from the upper end of the stack by a ring 20 of asbestos. A central hopper 10 is provided in the cover, and a series of hoppers 11 are situated around the edge. Broken, loose or granular refractory conducting material 14, such as lumps of coke or carbon, is fed through hoppers 11, while the central hopper serves for the introduction of the charges. The material 14, arranging itself in a vertical layer around the column of charge 15, decreases in cross-sectional area towards the hearth, and the heat generated in it by the passage of the current increases gradually. The carbide formed after the material has reached the zone of reaction may be tapped intermittently, or allowed to run out continuously, fresh material being fed through hopper 10, as the column of charge descends, while the material of the conductor is replenished through hoppers 11.

Electric Resistance Furnace.—Alfred H. Cowles, Cleveland, Ohio. Patent 750,093, January 19, 1904. Original application filed November 20, 1902. Divided April 21, 1903.

The specification illustrates several forms of apparatus suitable for carrying out the process described above. The first form is identical with that shown in Fig. 1. The second form is a horizontal furnace, the end walls, floor and roof of which are of refractory material. The hearth is a resistance conductor, either composed of loose material or of solid carbon. The upper surface of the conductor slopes towards the tapping hole, and one terminal of the source of current is connected to the conductor at the charging end, and the other at the dis-

charging end of the furnace. A current passing through the conductor thus heats it up more and more towards the discharging end, on account of the gradual decrease in cross-section and consequent increase of current density. A third form of furnace is shown, consisting of an inverted conical shaft, through the middle of which passes a resistance conductor with gradually decreasing cross-section, resting on a carbon hearth, which is connected to one terminal of the current, while the top of the resistance conductor is connected to the other terminal. The charge fills the annular space between the central conductor and the furnace wall. A fourth form of furnace shows a horizontal resistance conductor, constituted by a plate of solid carbon, which narrows down in width from the charging towards the discharging end of the furnace.

Process of Smelting Materials and Producing Carbides.—Alfred H. Cowles, Cleveland, Ohio. Patent 750,094, January 19, 1904. Application filed October 20, 1903.

In this process, which relates especially to the production of calcium carbide, the charge is preheated by passing hot gases through it, and then subjected to the action of the electric current, which is either passed through the heated charge, or its molten products, or through a separate resistance conductor. The current density is increased towards the point where the molten material is tapped out. Two types of furnaces for carrying out the process are shown in the specification. The first form shows an inverted conical shape of the lower part of the furnace, an iron shell lined with refractory material and water-jacketed all around. The bottom, as in the types described above, is formed of carbon and connected with one pole of the source of current. Near the top of the lower part there are introduced a number of cylindrical carbon electrodes, projecting to some extent into the furnace, and connected to the other pole. A preheating chamber of iron lined with refractory material such as siloxicon or magnesite, is supported upon and opens into the upper end of the furnace. The top of the chamber is provided with a bell and hopper. Pipes lead from the top of the furnace chamber proper into the preheating chamber, for the purpose of drawing off the combustible gases and burning them in order to preheat the charge. One or more auxiliary burners, supplied with fuel from other sources, may also be employed. An outlet pipe is provided at the top of the preheating chamber to draw off the products of combustion. The second form of furnace shows substantially the same form of preheating chamber, but the electric furnace proper is constructed horizontally with the carbon conductor forming the bottom and sloping, as in one of the types mentioned above.

Process of Effecting Chemical Changes.—Alfred H. Cowles, Cleveland, Ohio. Patent 750,096, January 19, 1904. Application filed November 5, 1902.

The process relates specially to the production of carbides, such as calcium carbide, and consists in passing an electric current through a body of carbide-forming materials, acting as a resistance conductor, and increasing the current density along the path of the current to a point where the heat generated by the resistance of the body causes the materials to react to form carbide. The type of furnace shown in connection with this process consists again of an inverted conical shaft of iron, water-jacketed and lined with refractory material. The iron shell is, however, separated into two parts, insulated from each other by a ring of asbestos. The upper part is provided with a ring of carbon, replacing the upper part of the lining and connected to one terminal of the currents. The hearth, composed of carbon, serves as the other electrode. It is not essential that the charge should consist of a mixture which is a conductor at ordinary temperatures, and the process may also be employed for the production of calcium carbide from a mixture of ground coke and lime. It is necessary in that case to provide an initial conducting path or high-voltage to start the operation.

Method of Electric Heating.—Alfred H. Cowles, Cleveland, Ohio. Patent 750,170, January 19, 1904. Application filed November 5, 1902.

The object is to provide a method wherein a body of conductive material in a molten state is interposed between electrodes to establish a path for the current, and a gradation in the current density obtained at the same time, the method being particularly applicable to the formation of calcium carbide. The furnace for carrying out the process has a circular body and hearth of refractory material, a carbon electrode extending through the bottom and serving as one terminal of the current. The body of the furnace is encased in a water-jacketed iron shell. An iron cover, with double walls, between which water is circulated, covers the top of the furnace, and the lower part of the cover is lined with carbon. The cover is connected to the other pole. A tapping hole is provided as usual. The current employed is stated to be of sufficient voltage to maintain within the furnace a body of molten or partially molten carbide, and partly reduced material, sufficient to nearly, or quite, fill the hearth.

Electric Furnace.—Alfred H. Cowles, Cleveland, Ohio. Patent 750,171, January 19, 1904. Application filed November 20, 1902.

The furnaces described in this specification are identical with those mentioned under the heading of the preceding process patents.

Process of Separating Metals from Matte or Ore. Paul Dankwardt, Deadwood, S. D. Patent 746,797, December 15, 1903. Application filed June 20, 1903.

The invention relates to a process for the smelting of matte or ores of similar composition, such as sulphide or sulpharsenide ores, in an electric furnace, with exclusion of air, the matte or ores having been previously mixed with a carbide or with carbide-forming materials. The operation is carried out in a furnace with a fireproof base, which supports water-jackets. The bottom slopes towards the tapping hole, and two electrodes of carbon are introduced into the furnace from opposite sides. The top of the furnace is provided with a hood of brick or metal, an outlet-flue for gases and charging openings with doors. The furnace is charged with a mixture of matte or iron sulphide or arsenide ore, which carries gold, silver, copper, lead or nickel, and a carbide or carbide-forming ingredients. If limestone and carbon are used, 0.473 parts of limestone and 0.066 parts of coke are used for each ton of ore. The proportion of the matte or ore and the carbide or carbide-forming materials, is stated to be such that the carbide will be just sufficient to reduce all the sulphides or arsenides of the valuable metals which are to be separated, but will not be sufficient for the reduction of the sulphide of iron. The reaction is stated as follows:

$$2CaCO_3 + 2C + CuS + PbS + FeS = Cu + Pb + 2CaS + FeS + 2CO + 2CO_2,$$

in the case of a copper-lead-iron matte carrying gold and silver. It is stated that while the process is going on, there will run out of the furnace a metal or an alloy carrying the gold and silver of the matte or ore, and a changed iron matte and calcium sulphide or arsenide with some slag formed by the impurities of the charge. If, instead of the lime and carbon, a mixture of oxide or carbonate of iron and carbon be used, the sulphur or arsenic, etc., will be taken up by the iron of the carbide of iron formed in the reaction, and an increased quantity of sulphide of iron will run out of the furnace.

Process of Recovering Zinc from Sulphide Ores. P. Dankwardt, Deadwood, S. D. Patent 746,798, December 15, 1903. Application filed August 15, 1903.

The inventor states that the process is particularly adapted to the treatment of ores which carry lead-zinc sulphide copper-zinc sulphide, concentrates from these classes of ores, which are too low in value for direct treatment, and furnace products

such as flue-dust, matte, etc. The process is carried out in an electric furnace, which consists of a foundation of refractory material, on which rest the walls of a retort. The latter is cooled by water-jackets. The rear end of the retort opens just level with the bottom of a vertical shaft, which is provided with a cover. A carbon block is introduced through a perforation in the side of the retort, and another carbon block enters through an opening in the arched top of the retort. A charge-opening and a tapping hole are also provided, and a pipe leads from the retort to a receptacle with a small outlet pipe for gases. The ore is dried and mixed with fluxes and such amounts of an alkali salt or a carbide or carbide-forming materials, that all the sulphur combined with the zinc, lead or copper of the ore will find sufficient alkali metal to combine with when the charge is heated. The mixture is introduced through the shaft and is covered by coke introduced through the opening in the top of the retort, after which current is put on the furnace. If iron pyrites are present, the ore should be mixed with such proportions of alkali salt and carbide-forming materials, that enough of the sulphur of the iron pyrites is withdrawn, so as to cause the latter to be transformed into an iron matter. The inventor illustrates the process by describing the reactions in the case of an ore composed of

$$ZnS + PbS + CuS + FeS_2 + SiO_2 + FeO.$$

This is mixed with sodium sulphate, lime and coke. The reaction is stated to proceed, probably in such manner, that the sodium sulphate is first reduced to sulphide, with evolution of carbon monoxide. As the temperature rises to the point of formation of carbide, the latter reacts with the sodium sulphide, forming calcium sulphide and metallic sodium, which latter in statu nascendi attacks the heavy metal sulphides, and reforms sodium sulphide, setting free the heavy metals. The silica and the protoxide of iron are fluxed off by the addition of limestone. As carbide-forming materials, the inventor prefers to use limestone or iron ore and coke or coal, but alumina or magnesia may also be used. The alkali salt is preferably sodium sulphate. The mass is said to melt under the influence of the heat of the current, the zinc going off in the state of vapor and condensing in the receptacle m, while the other metals will run down the inclined bottom of the furnace. They are tapped out at the tapping hole, together with the sulphides of sodium and calcium, the iron matte and the slag. The metals and the matte are allowed to settle out, and the sulphides and the slag are broke up after cooling, and the sodium sulphide leached out with water. It is proposed to treat this solution with a current of CO_2, thus converting the sodium sulphide into carbonate and driving off the H_2S. The latter is to be turned either into sulphur or sulphuric acid.

Electric Furnace.—Le Roy W. Stevens and B. Timmermann, Chicago, Ill. Patent 749,460, January 12, 1904. Application filed August 8, 1902. Renewed May 26, 1903.

The furnace is designed for obtaining metals from their ores, and for the manufacture of borides, silicides, carbides, etc. The construction shows a vertical cylindrical shaft or flue, the lower end of which is inclined and, gradually narrowing down in cross-section, opens into an electric furnace. The latter is of well-known construction, with a sloping carbon bottom forming one electrode, while one or more vertical carbons depend from the top and constitute the other electrode. A tapping hole is provided at the lowest point of the sloping bottom. A flue leads from the upper part of the electric furnace chamber to a point near the top of the vertical chamber. Oil burners are also arranged near the top of the latter. A hopper and screw conveyor feeds the charge into the furnace. At the lower end of the vertical flue a pipe is provided, through which the gases are drawn off by means of a fan or similar apparatus. The gases generated in the electric furnace thus are drawn through the pipe connecting the furnace with the vertical shaft, and travelling downward pass out through the lower pipe. The flame of the oil burners is similarly deflected downward. This construction is intended to effect a thorough preheating of the charge before it is delivered into the electric furnace. Several modifications of the apparatus are described and illustrated in the specification, in which the electric furnace chamber is mounted on trucks and so arranged that it can be detached and removed for repairs.

Electric Furnace.—Le Roy W. Stevens and B. Timmermann, Chicago, Ill. Patent 749,461, January 12, 1904. Application filed October 29, 1902. Renewed June 17, 1903.

This furnace is an improvement on the one described in the preceding specification, inasmuch as the inventors show means for preventing the gases generated in the electric furnace part from being drawn out directly through the lower pipe, instead of passing into the pipe leading to the top of the vertical chamber, and then traveling down the latter to the outlet pipe. These means consist in the arrangement of a pushing device, situated where the vertical flue discharges into the electric furnace, which operates in such a manner that there is always a certain portion of the charge allowed to accumulate in the lower part of the vertical chamber, below the mouth of the outlet pipe, thus sealing the lower part of the vertical chamber and forcing the gases to travel in the prescribed path.

Furnace.—Le Roy Stevens and B. Timmermann, Chicago, Ill. Patent 749,462, January 12, 1904. Application filed October 30, 1902.

This furnace is constructed on similar lines as the two preceding ones, with this difference, however, that there is only one vertical preheating chamber provided for feeding four electric furnaces, one situated on each side. A portion of the charge is allowed to accumulate in the lower part to act as a seal for the gases as described above, and provision is made to apply additional heat to this part in order to keep the material contained in it hot. The construction of the electric furnace part and the vertical chamber in other respects is substantially the same. A safety-valve is provided at the top of the vertical chamber in order to guard against an excess of gas being supplied to the latter.

Electrometallurgy of Iron and Steel.—H. Harmet, St. Etienne, France. Patent No. 750,361, January 26, 1904. Application filed September 30, 1901.

The apparatus in which this process for the reduction of ores is carried out looks much like the ordinary blast furnace, and is provided, like the latter, with bell and hopper. The ores mixed with an excess of coke are fed in as usual, but instead of there being one down-comer for the gas, there are two, a fan is placed in one of them, and the inventor purposes to suck a portion of the gases off and blow them through water-cooled tuyeres into the furnace again right into the zone of fusion. The construction of these tuyeres is rather peculiar. Insulating supports of porcelain are situated inside of the tuyere casing, serving to carry the electrodes. It is thus seen that the electrodes are situated right in the tuyeres and no means whatever is shown whereby they can be adjusted. Moreover, the electrodes have a longitudinal hole through their center, and the supports are pierced to permit the entrance of the gases delivered to the tuyeres into the fusion zone. The gas entering the fusion zone under pressure is forced upwards into the charge, thus transmitting to the latter the excess heat of the fusion zone.

Electric Furnace.—R. C. Contardo, Sèvres, France. Patent 750,753, January 26, 1904. Application filed August 24, 1900.

The inventor claims an electric arc furnace, comprising a hearth having an inclined surface, electrodes above the same, an arch above the hearth, consisting of two symmetrically and downwardly inclined surfaces and side walls parallel to said arch, forming inclined flues. The ores to be treated are introduced through bell and hopper at the top of the furnace, and

descend into the hearth by means of sloping plates, which form the roof of the melting chamber. The whole weight of the ore charge rests on these sloping surfaces, and yet the inventor claims that those plates are thin and good conductors, made preferably of plumbago. This sample will suffice to show the practicability of the inventor's proposition; the specification abounds in similar ones.

Reduction of Metals and Alloys.—F. J. Tone, Niagara Falls. Patent 754,122, November 24, 1903. Application filed January 22, 1902.

The invention applies to the reduction of metals, such as silicon and aluminium, the temperatures of reduction and volatilization of which are nearly the same. The difficulties encountered formerly in regard to the volatilization of the metal and its union with the uncombined carbon of the mixture to form carbides are stated to be avoided by proper conditions of temperature, proper distribution of heat, and proper arrangement of the charge to be treated in the furnace. The operation is preferably carried out in an incandescent furnace, shown in cross-section in Fig. 2. The walls 2 are constructed of refractory brick, and the floor 3 is composed of a thin layer of refractory brick or tile. Spaces 4 are provided in the bottom for the purpose of allowing the reduced metal to fall through and collect in receptacles 6, arranged in a substructure of brick piers 5, on which the flooring tiles are supported. Carbon blocks 7, 8 are introduced into the furnace near the bottom and the top, and are connected in the middle of the furnace by a vertical column 9 of carbon blocks preferably piled together with intervening spaces. The current in passing through the resistance column from one terminal to the other heats the mixture with which the furnace is filled, evenly and gradually, allowing the reduced metal to collect in globules and sink to the cooler portions of the furnace, and into the receptacle 6. Another type of furnace is illustrated in the specification in which the electrodes are introduced in the same horizontal plane at the ends of a horizontal furnace. The resistance arrangement consists of two or more vertical columns, constructed as described above, set on the floor of the furnace and connected in series by carbon bars disposed alternately at the upper and the lower ends of the columns. Spaces in the floor of the furnace for the metal to pass through and receptacles underneath are provided. The incandescent type of furnace was chosen in order to obtain a wide zone of reaction and a slowly developed temperature, high enough for the reduction of the metal, but not so high, when the latter is immediately removed, as to cause its waste by volatilization and conversion into carbide.

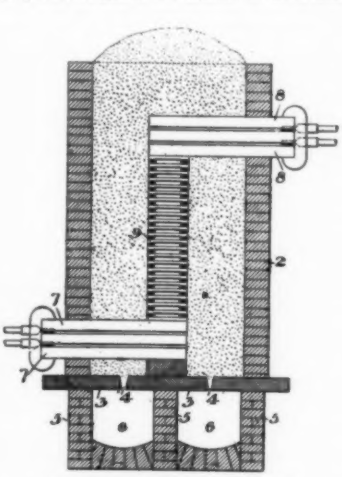


FIG. 2.—SILICON FURNACE.

Process of Electrically Heating Articles.—E. F. Price, Niagara Falls, assignor to Union Carbide Co. Patent 752,357, February 16, 1904. Application filed November 5, 1902.

The process is primarily intended for baking the carbon bars which are used as electrodes in carbide and other furnaces. The furnace used for heating the articles is a rectangular fire-brick structure, the carbon block electrodes being introduced into the end walls. The inner ends of the electrodes project slightly into the furnace and may be protected by a molded carbon block or facing. The articles to be treated are placed in the furnace, separated from each other and surrounded by a filling of material, which is normally a poor conductor, but will become a good conductor when heated. Finely powdered anthracite has been found suitable for this purpose. A central resistance core connects the two electrodes, and the whole is so arranged that the current will in the first instance pass entirely through the core, but will gradually shunt through the packing material as it is converted into a better conductor by the heat generated in the core. The articles to be heated are placed end to end, and a portion of the current may also pass through them and assist in the heating.

Process of Heating Articles by Electricity.—E. F. Price, Niagara Falls, assignor to Union Carbide Co. Patent 752,358, February 16, 1904. Application filed November 5, 1902.

The process differs from the preceding, in so far as the current is passed through the resistance conductor and the articles to be heated, the preferred mode of operation being to pass the current first through the core and then through the articles. The furnace, a rectangular fire brick structure as above, contains a group of electrodes, situated in each end wall and arranged concentrically. They are constructed of a central carbon disc, surrounded by a layer of refractory insulating material, which, in its turn, is surrounded by a ring of carbon, serving as the second electrode. A layer of insulating material separates this again from a second carbon ring, serving as the third electrode, each of the electrodes having terminals for the introduction of the current. The central carbon disc is in contact with a core of broken coke. The articles to be heated, *e. g.* rectangular carbon bars, are placed in concentric layers around the core, the ends of each row of bars being in contact with the corresponding electrode rings at each end of the furnace. The heating is preferably effected by first passing the whole or the major portion of the current through the central core, until the latter becomes heated to incandescence. The switches are then shifted to divert the whole or a considerable part of the current from the core to the first ring electrodes, and the articles lying between them. As soon as they are heated to the desired temperature, the whole or the major portion of the current is diverted to the second ring electrodes and the articles lying between them.

APPARATUS AND PROCESSES FOR THE ELECTROLYTIC PRODUCTION OF METALS AND COMPOUNDS.

Apparatus for Electrolytic Decomposition of Alkali Chlorides. J. J. Rink, Elsinore, Denmark. Patent 748,985, January 5, 1904. Application filed April 4, 1902.

The apparatus represented in Fig. 3, in longitudinal cross-section, belongs to the type of mercury cells, and is divided into a series of anode and cathode chambers. Salt solution is admitted into the anode compartments *a*, which are open at the bottom and at one side, and rest on lugs so as to raise them somewhat above the bottom of the containing vessel A. The open side of each anode compartment communicates with a passage or compartment running along one of the long sides of the containing vessel. This passage serves for the introduction of the brine and the drawing off of the chlorine. The anode chambers are stated to be constructed of any suitable "conductive" material, which is not liable to be affected by the solutions or gases generated during electrolysis. It would be

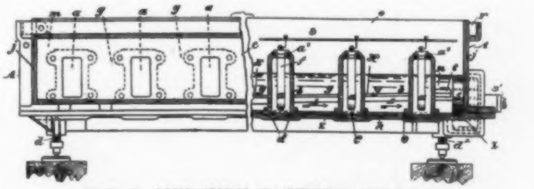


FIG. 3.—MERCURY CATHODE CELL.

very interesting to know what such conducting material is like, but that information is not given by the inventor. The containing vessel A is stated to be made of similar material. A number of carbon rods are arranged in the anode chambers, and are introduced through the top and insulated from the cell material by suitable washers. The width of the anode chambers is given as being from three to five centimeters, ten centimeters at the maximum. The discharge compartments *g* are situated between the anode chambers and their width is about twice that of the latter. The mercury travels through one cell after the other in the direction of the arrow, and at the end of the apparatus is raised by means of a screw wheel *s* into a tank *t* which delivers into a trough *x*, through which it returns to the other side of the apparatus and re-enters into circulation. A solution of water or weak alkali is placed, as usual, into the discharge compartments *g*. The bottom *z* of the containing vessel is provided with raised portions *e* within the decomposing cells, in order to get as thin a sheet of flowing mercury as possible. No data as to current density at anode and cathode are given. The apparatus with its large number of more or less delicate parts, involving, as it does, the necessity of keeping long joints tight, seems needlessly complicated. The uniform movement of mercury over a large surface is not an easy proposition on a large scale in practice. It is also much to be doubted, whether the amalgam will discharge itself completely in the short space between succeeding decomposition chambers, in view of the well-known tenacity with which it retains the alkali metal. It will probably become more concentrated in each succeeding chamber, leading to a correspondingly increased loss of alkali by reactions taking place there.

Production of Hydroxides and Oxides of Metals by Electrolysis.—F. F. Hunt, New Brighton, N. Y. Patent 748,609 January 5, 1904. Application filed January 22, 1903.

The process consists in the electrolysis between electrodes of the same metal, the hydroxide or oxide of which is desired of a suitable electrolyte, which consists preferably "of a neutral solution and of an alkali or alkaline earth, whose acid radical will form a salt of the metal of the anode which is soluble in the electrolyte." The polarity of the electrodes is reversed at suitable intervals. During electrolysis soluble salts are produced at the anode, which react with the caustic alkali formed around the cathode to produce the hydroxide. In the production of hydroxide of tin a five to ten per cent solution of sodium chloride is electrolyzed at a temperature between 30° and 40° C., with a current density of from twelve to fifteen amperes per square foot of anode. The voltage between the electrodes is 2½ volts, and the polarity of the electrodes is reversed at intervals of about one minute. The writer, in following a similar line of procedure as that outlined in the specification, in experiments carried out several years ago, experienced a great deal of trouble from the deposit sticking to the electrode on reversal of the current, causing a great increase in resistance and falling off in yield.

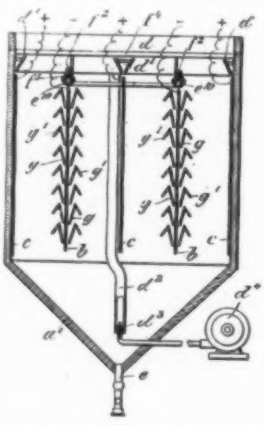


FIG. 4.—CELL FOR GOLD EXTRACTION.

Process and Apparatus of Extracting Precious Metals by Electrode.—F. A. Feldkamp, Newark, N. J. 749,855, Jan- and 749,844, January 19, 1904. Application filed October 25, 1902.

The apparatus is illustrated in Fig. 4, and consists of an electrolyzing tank *a*, with a printed bottom *a'* provided with a discharge door. Alternating cathodes *b* and anodes *c* are vertically suspended in the tank. An ore pulp tank *d* extends across the upper part of tank *a*, which communicates with a series of launders *d'*, the bottom of which is perforated, and which are disposed right above the anodes *c*. The pulp in flowing out of these perforations flows along the anodes and accumulates in the bottom of the apparatus, whence it is forced up again through pipe d^2 by means of an air-blower d^4 and nozzle d^3. It then circulates again through the apparatus as before, until the values are leached out by the solvent, preferably cyanide of potassium, mixed with the pulp. The cathodes *b* are kept amalgamated by a stream of mercury which falls upon them from a number of perforated iron troughs e^{10} arranged directly above them. A distributing device is also provided. In order to insure a perfect amalgamation of the cathodes, and to prevent mercury from reaching the anodes, a number of deflectors *g* are provided, which have a downwardly inclined guard g^1 on the side towards the anodes, in order to direct the descending stream of pulp towards them. The mercury falls down into the pointed bottom and is forced up again by an air-lift, which delivers it into a pot provided with an amalgam filter. From there it flows in a sinuous way through a cleaning tank filled with dilute sulphuric acid, whence it is returned into the distributing trough, and begins its circulation again. When the values have all been extracted from the pulp, the latter is discharged through the discharge door in the bottom. The electrolysis of the cyanide solution takes place, the values being dissolved out of the pulp passing the anodes and precipitating as amalgam upon the cathodes. The coarser particles of gold are claimed to be immediately amalgamated and retained on the cloth filter mentioned above. The amalgam which accumulates on the plates is from time to time removed and treated in the usual manner.

STORAGE BATTERIES.

Method of Producing Electrodes for Storage Batteries.—F. A. Feldkamp, Newark. Patent 748,940, January 5, 1904. Application filed April 17, 1903.

In carrying out his method, the inventor places one or more pieces of porous material, such as linen, cotton, cheese cloth, etc., against a conducting plate of preferably lead and sews them to the plate. Zinc dust or granular zinc is then sprinkled on the material until it becomes thoroughly impregnated. The plate is then suspended in a solution of acetate or nitrate of lead, whereupon it is claimed that the lead separates out in spongy form from the solution on meeting the particles of zinc, and becomes thoroughly imbedded in the material, the plate being thus substantially converted into a lead plate. The plate is then rinsed in clear water and preferably passed between a set of rolls to remove the moisture and compress the deposit to some extent. Several modifications of the above treatment are given in the specification.

Process of Producing Electrodes for Storage Batteries and Electrode. F. A. Feldkamp, Newark, N. J. 749,855, January 19, 1904. Application filed May 19, 1903.

The process consists in taking a lead plate or grid, and wrapping it in such material as mull linen, mosquito netting, or similar material, mosquito-netting with from eight to ten threads each way per square inch being stated to be admirably adapted for the purpose. Three layers of the material are wound on each side and sewed fast to the plate. The active material is then applied in a plastic or semi-plastic condition to one side of the plate and forced into the porous material by pressure, until it fills the openings in the plate or grid, and comes to the surface on the other side of the plate. The latter side is then similarly treated, the result of the procedure being a plate of extreme hardness, the active material of which is prevented from peeling, blistering, etc.

Electrode.—Rudolf Hager, Berlin, Germany. Patent 749,185, January 12, 1904. Application filed January 31, 1901.

The electrode described in this specification is built up of a number of superimposed V-shaped channels, connected at several places by upright strips of lead. The channels are bent into a circle, the inventor claiming that deformations and tensions in the electrodes can be obviated if each channel, instead of being a complete ring, is slit at one point along its circumference. Modifications of channels, *i.e.*, such with corrugated or slanting walls, and spiral-shaped channels, are also described.

Battery Plate.—Oskar Frank, Detroit. Patent 749,785, January 19, 1904. Application filed May 2, 1903.

The plate consists of a rectangular frame, with the usual connecting lug, and a series of vertical and horizontal bars. The vertical bars have the same thickness as the plate, while the horizontal bars are of triangular cross-section and about one-half the thickness of the plate. They are staggered on opposite sides of the plate with the base of the triangle flush with the faces of the plate upon opposite sides. In casting the plates, thin webs connect the bases of opposing triangular ribs, which webs are then punched through from opposing sides to form triangular hooks, which are claimed to be highly important in holding the active material.

Electrical Accumulator.—Ch. P. Elieson and V. de Bobinsky, Paris, France. Patent 12,195, Reissue. Original 692,433, February 4, 1902. Application for reissue filed October 26, 1903.

The plates of the accumulator consist of two columns composed of a number of lead strips, which are alternately corrugated and flat. A compound strengthening rib is provided in the middle.

Plate for Storage Batteries.—Joseph Bijur, New York. Patent 751,046, February 2, 1904. Application filed March 31, 1902.

The plate shown in the specification is provided with a number of panels, which are preferably cast separately from the rest of the plate. The panels are composed of a number of vertical strips with cross members supporting them. The spaces between the strips are narrower at their ends, thus strengthening the juncture between the strip and the cross members. The plate is of the Planté type, large, active area, great strength, freedom of the active strips to elongate without causing strains or buckling the frame and freedom of circulation of the electrolyte being among the advantages claimed for it.

Storage Battery Plate.—Charles B. Askew, Chicago, Ill. Patent 751,772, February 9, 1904. Application filed May 30, 1903.

The plate is constructed with retaining and supporting projections for the active material, the upper and lower faces of which are disposed at right angles to the mean plane of the plate body or grid, and are also provided with key apertures extending entirely through the grid, so that when pasted on both sides, the active material upon opposite sides of the plate will be keyed together to afford lateral support to it.

Electric Battery.—W. S. Bryan, Cincinnati, Ohio. Patent 750,250, January 26, 1904. Application filed September 28, 1903.

The cell is constructed with a containing jar at the bottom which is provided with an air pressure pipe. The electrodes are arranged on top of the containing jar. When the battery is not in use, the liquid is contained in the jar. It is forced up by air pressure, by connecting the above tube with a source of compressed air, when it is desired to start the battery.

Storage Battery Plate.—Joseph Bijur, New York. Patent 744,895, November 24, 1903. Application filed August 14, 1900.

The plate is intended for the Planté type of storage batteries, and consists of a series of panels, which are composed of minute ribbons of lead, lying parallel with each other, and united at their ends into ribs or supports of the plate. Preferably alternate strips are slightly corrugated to permit the free circulation of the electrolyte. A method is outlined in the specification by which the ends of the strips are fused into the ribs of the plate.

Accumulator Plate.—F. W. Buehne, Freiburg, Germany. Patent 745,274, November 24, 1903. Application filed October 6, 1900.

The plate consists of a grid, which supports a material formed of a felted mass of long, fine-cut filaments of metal. The metal fibres lie across one another in all directions, and are lightly compressed generally, but more firmly compressed along certain lines, so as to give more rigidity to the mass. The entire plate may be made of a single long, uniformly cut, felted metal filament.

GALVANIC ELEMENTS.

Galvanic Battery.—D. L. Winters, Chicago. Patent 744,989, November 24, 1903. Application filed October 5, 1903.

The invention has for its object to provide a simple structural arrangement, by means of which the positive and negative electrodes of batteries can be connected in series with but little change in the terminal line connection. A mechanical arrangment for this purpose is described in detail in the specification.

Pocket Battery.—W. Heym, Berlin, Germany. Patent 744,758, November, 24, 1903. Application filed August 15, 1903.

The inventor claims the combination of two holders put together so as to form a vessel, each holder containing an active mass and a metal strip, and having a contraction, with an electrolyte filled in the space between the two holders, and a seal above the contraction.

Flexible Connector for Batteries.—Patrick Kennedy, New York. Patent 745,193, November 24, 1903. Application filed June 30, 1903.

The connector comprises a socket piece of preferably a compound of lead and antimony which is not affected by acid fumes. It is provided with a head which contains a projecting screw of harder metal, the end of which is fastened in the head. A nut of the same metal as the socket piece is provided, which in its interior contains a screw-threaded block of harder metal, intended to engage with the screw on the socket piece.

Exciting Compound for Batteries.—A. J. Marschall, Little Falls, N. Y. Patent 750,871, February 2, 1904. Application filed May 21, 1903.

The battery fluid consists of water, 100 parts by weight; zinc chloride, 80 parts; ammonium chloride, 6 parts. The inventor claims an exciting compound for batteries, consisting of a solution of zinc chloride and ammonium chloride, the zinc chloride being in excess of the ammonium chloride.

MISCELLANEOUS.

Process of Electrolytically Purifying Juices.—A. Kollrepp and A. Wohl, Charlottenburg, Germany. Patent 751,179, February 2, 1904. Application filed June 10, 1902.

The process is carried out in a tank, provided with anode plates of carbon, two anodes being used for each cathode. Situated between them are diaphragm cells, upon which are stretched parchment sheets, a sieve-like perforated iron plate at the inside of these parchment sheets forming the negative electrode. Emptying and filling of the diaphragm cell is done

by syphon tubes. The process, as applied to beet juice, obtained by diffusion, consists in precipitating with approximately 0.3 per cent of lime and carbonic acid, such salts as are insoluble in the further steps of the process. The juice is then filter-pressed and mixed with eight to ten per cent of its weight of moist saccharate of lead, containing fifty per cent of water. It is then subjected to electrolysis at a temperature of about 60° C., during active stirring, by blowing in air. At a distance of about three centimeters of the electrodes, and eight to ten volts tension, the current density is 1½ amperes per square decimeter at the beginning, and 1 ampere average. At an average ampereage of 1 ampere per square decimeter, one-fourth square meter surface of electrodes and 10 hp. hours are stated to be consumed for a cubic meter of juice in a day. The alkali is extracted by electrodialysis, the total amount of potassium hydrate diffusing to the negative electrode being stated as about one per cent of the weight of sugar purified by electrolysis. The compounds of lead of the non-sacchariferous substances obtained by electrolysis are mixed with discharged sacchariferous liquid and excess of alkali, the saccharate of lead thus obtained being separated by filter pressing.

Apparatus for Purifying Liquids.—Otto Kartzmark, Brooklyn. Patent 751,986, February 9, 1904. Application filed December 26, 1900.

The apparatus consists of a long tank with an overflow at the end leading to a settling tank. Placed within this tank is a smaller tank, open at the bottom, but so arranged that the liquid can overflow at the top. A series of detachable electrodes are supported in the smaller tank at a suitable distance above the bottom of the apparatus. The liquid is passed upwards between the electrodes, and into the larger tank, whence it flows into a settling tank.

Molding-Case for Use in Electrotyping and Process of Manufacturing Same.—W. H. Welsh, Collingswood, N. J. Patent 752,493, February 16, 1904. Application filed October 13, 1903.

The objects of the invention are to prepare the molding-case in such a manner, that the sticking of the impressionable composition of the case to the cut, half-tone, etc., while making the impression, is prevented, and to also prevent the slipping or spreading of the impressionable composition, while the impression is being made. This is attained by coating the composition with flour of copper, an impalpable powder obtained by grinding the siftings of electrodeposited copper. After this the case is passed through the ordinary steps of electroplating, i. e., making the impression, blackleading and treatment in the electrolytic bath.

Current Interrupter.—T. A. Houghton, Rochester, N.-Y. Patent 745,280, November 24, 1903. Application filed April 1, 1903.

The invention relates to an interrupter of the Wehnelt type. It comprises a jar partially filled with dilute sulphuric acid, a cathode consisting of a coil of lead pipe through which water circulates, being arranged on the bottom of the jar. A cover with suitable openings for the passage of the anodes and carrying a superstructure which supports the mechanical construction for the interrupting device, is also provided. Each of the two anodes consists of small rods or wires of platinum, which are covered by insulating members in the form of glass tubes. In the operation of the interrupter a rotating motion is imparted to a shaft, which by means of two cross-heads gives an up and down reciprocating motion to the glass tubes covering the anodes, the lower ends of which in the electrolyte are thus alternately sealed and unsealed. Provision is also made whereby the circuit connected with an anode is positively broken or disconnected when the anode is sealed by its insulating member, thus directing all the current into the anode which is unsealed. The frequency of the vibrations may be varied by revolving the driving shaft at greater or less speed, and the intensity of the current may be varied by adjusting the anodes vertically or decreasing the surface of them, which is unsealed by the movement of the insulating tubes.

Apparatus for Sterilizing Water.—H. J. Wessels, Paris, France. Patent 751,886, February 9, 1904. Application filed June 22, 1903.

The ozonizers of this apparatus have electrodes which are formed of a series of points, arranged in a semi-circle a short distance above a semi-cylindrical trough of metal, the electric discharges taking place between the points and the metal. The trough is provided with a jacket of enamel and a cooling fluid circulates in the space thus formed. The ozonized air is cooled in its passage from one ozonizer to the other, and then mixed with the water to be sterilized.

SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.

INDUSTRIAL ELECTROCHEMISTRY.

Formation of Periodates.—For some time E. Mueller has studied the electrolytic formation of periodates. He has formerly described a method in which he used a diaphragm to prevent the periodate which was formed at the anode, from reaching the cathode and being reduced again. He later found that this reduction is successfully prevented without diaphragm, if some chromate is added to the solution (the same device has also proved useful in other cases). In the *Zeit. f. Elektrochemie,* January 22, the same author now gives the following rules for producing periodates of alkalies. In normal potassuim hydroxide, which contains 0.1 per cent of the volume K_2CrO_4, and is saturated with potassium iodate, two bright platinum wires are placed as cathodes at both sides of a sheet platinum anode; with an anodic current density of 0.05 ampere per square centimeter, and, at the ordinary temperature of the room, it is possible to oxidize nearly all the iodate to periodate. The author describes a long series of experiments which were made to explain some points in the theory of the process.

Electric Furnace Processes for Nickel Production.—In an article published in *L'Ind. Electrochim.*, December, H. Becker discusses the possibility of the treatment of New Caledonian ores for the production of nickel. These ores generally contain 9 to 17 per cent protoxide of nickel, 41 to 46 silicic acid, 5 to 14 iron peroxide, 1 to 7 alumina, 6 to 9 magnesia and 8 to 16 water. There is generally much iron in the ores, so that by reduction and fusion, an alloy rich in iron is obtained. Treatment of the ores in a blast furnace produces an iron-nickel alloy, and there is no suitable method for getting the nickel out of it. The same disadvantage is in the use of the electric furnace. Moreover, carbon and silicium are also among the impurities. Heiberg has proposed to treat in the electric furnace a mixture of oxide of iron and nickel with sufficient coke and lime, to produce ferro-nickel and calcium carbide as by-product; this would be possible with pure raw materials, but not with the New Caledonian ores, which contain considerable silicium. For the refining of nickel Le Verrier has proposed to electrolyse in a diaphragm cell a solution of a double chloride

of ammonium and nickel, with the impure nickel anodes and pure nickel cathodes. The nickel is deposited upon the cathode, and the iron is separated from the electrolyte according to the degree it dissolves, either by blowing air into the anodic compartment, if the quantity is small, or by the addition of chlorine, if the quantity is large. This process has given good results in the laboratory, but has never been employed on a large scale. While the electric furnace is not applicable to the direct treatment of the New Caledonian ores, yet it may be used for the reduction of nickel oxide, obtained in the chemical process. The only difficulty is to get the nickel free from carbon. For this purpose Siemens & Halske separate the electrodes from the fused nickel by a slag of magnesia, with an addition of fluorspar. (See p. 466 of v. I., of this journal.)

Caustic Soda Industry.—The following quotation from our British contemporary, the *Chemical Trade Journal*, January 16, should interest our readers: "The American production, both of alkali and bleach, has now reached such proportions that it has to be reckoned with, and, though no immediate extension of operations is contemplated, it is very probable that we shall hear more in the near future. The Michigan Alkali Co., at Wyandotte, have been busy rebuilding the works that were destroyed by fire. It is rumored that they are now ready to start again with a production of 500 tons of ash per day, and 30 tons a day of bicarb. A large coke plant has also been added, which will supply both the No. 1 and the No. 2 works with coke and ammonia, so that it will be seen that these works are now as fully equipped as any British or Continental establishments. The No. 2 works of this company make nothing but caustic soda and cement, the production of the former amounting to over 2200 tons per month. The cement works are large enough to work up all the lime mud produced in causticising the ash. The Barberton works is running full time, and turning out 200 tons a day of soda ash, and 40 tons a day of caustic soda, from which figures it is easy to comprehend the importance of the American competition. It will be a poor lookout for the caustic soda trade of this country (England) should the makers fail to introduce such labor-saving and fuel-economizing machinery as are normally employed in the States. The Bell electrolytic alkali plant, lately installed at the works of the Pennsylvania Salt Co. (in Wyandotte, Mich.; the Bell process uses a mercury cathode), does not seem to have reached perfection. In fact, it is a long way from this, as, though they have been working on and off for over six months, they do not seem to have made much headway. Up to Christmas last, they had packed only five chambers of bleach, of an average strength of 32 per cent, and three small pots of caustic, of very good quality, but something much more than this is necessary for a satisfactory financial issue. We are not surprised at the foregoing results, as the balance sheets of our own (English) companies seem to point to the fact that there is not much difference in the results to be obtained by the application of electrolysis to the decomposition of common salts, over and above those to be obtained by the Leblanc process."

Hydroelectric Plants and Electrochemistry in France.—In the issue of January 22 of the Lond. *Elec. Review* M. Bloch describes a number of water-power plants, partly supplying electrochemical works in the district around Grenoble, which was the headquarters of the Congress de l'Houille Blanche (White Coal, meaning the waterfalls utilized for power). Various electrochemical plants are along the Romanche River, and on the Arc River. Among the most interesting is La Praz, with an output of 12,000 hp., engaged in the production of aluminium, two falls being used, of heights of 80 and 33 meters, each with a volume of 12 cubic meters per second. The author gives the following figures for the development of waterfalls in the Alpine region, and the utilization thereof:

	HP.
Aluminium works	22,536
Metallurgical factories	20,485
Chlorate of potassium works	9,000
Calcium carbide works	104,466
Sodium chlorates	13,500
Transmission of power and lighting	48,727
Various industries	19,989
Total	238,703

The power used in "various industries" is mostly furnished to paper and pulp mills, cement works, porcelain works, etc.

Calcium Carbide Plants.—In the issue of January 15 of *Jour. de l'Electrolyse*, a serial begins on calcium carbide plants. The first article deals with the two water-power plants of the Société des Carbures Métalliques in Savoy. One plant contains three 2200-hp. turbine-driven alternators, the other five 700-hp. turbine-driven alternators. The voltage of the transmission to the transformer substation at the carbide works is 15,000. No description is given of the furnace equipment of the carbide plant.

Electrolytic Soda and Chlorine Plant.—C. Domar describes in *L'Eclairage Elec.*, January 30, the plant at Gavet-Clavaux of the Société des Soudières Electrolitiques, near Grenoble. It contains two turbine-driven direct-current dynamos, giving 5000 or 2500 amperes at 75 or 150 volts respectively. No description is given of the manufacture of caustic soda and chlorine.

Electrolytic Production of Copper Wire.—Although much time and money has been spent on processes for the production of copper wire by electrolytic methods, up to the present they have not been commercially successful; a concise illustrated summary of the various attempts made in this direction i given in the January issue of *Electrochem. and Met.* The various processes are divided into these three classes: first, a traveling cathode of fine wire is thickened by electrodepositing copper on it, and is again reduced by passing through a draw-plate; second, the production of copper cylinders or discs which are cut up into strips or spirals; third, the electrodeposition of copper in the form of a strip deposited on a thread or strip wrapped around a revolving cathode.

Electromagnetic and Electrostatic Separation.—A paper on this subject was recently presented by D. Korda to the International Society of Electricians in Paris. A reprint in full begins in *L'Eclairage Elec.*, February 6 and 13. The author first discusses the electrostatic methods of Blake and Negreano and then begins to give a review of electromagnetic separators

Lectures on Electrochemical Industries.—A portion of lecture notes on electrochemistry, prepared for the Electrical Engineering Department of Columbia University, is published by F. B. Crocker and M. Arendt in the November issue of the *School of Mines Quarterly*. After a brief classification of the subject matters of electrochemistry the authors outline the following processes: Electrolytic refining of copper, electrolytic production of aluminium, caustic soda, potassium chlorate, various furnace processes, especially calcium carbide, carborundum, artificial graphite.

Soldering Aluminium.—An anonymous writer in the *Amer Machinist* of January 7 is surprised that so many people do not know how to solder aluminium. To make the solder, he uses bismuth, 10 parts; zinc, 30 parts, and pure tin, 60 parts. He advises to melt the bismuth and zinc first, then add the tin; pour the whole into molds about a foot long and about the size of a pencil. To do the soldering he uses a stick of solder, an old nickel aluminium spoke and a blow torch. The pieces to be soldered are held in a vise or any convenient place, the flame from the torch is applied to them, until they are hot enough to melt the solder, when it is applied, the surface to be soldered is then scraped with a file or scraper. "Melt the solder on to each piece and work it around with the spoke: now hold the parts together in front of the flame, move the

torch away and let them cool, and the mend will be as strong as if it never was broken."

THEORETICAL AND EXPERIMENTAL.

Dielectric Constants of Solvents and Solutions.—The January issue of the *Jour. of Phys. Chemistry* contains a paper by H. E. Eggers, who has made researches in continuations of the work of Schlundt, and tested various hitherto uninvestigated solvents, mostly sulphur compounds. He found, notably in the case of nitriles, that the dielectric constant is not an additive property, but depends to a very great degree on the relative chemical structure of the molecule. In the case of the nitriles a single cyanogen radical at the end of a chain has the effect of raising the dielectric constant to an enormous degree. Two cyanogen radicals, however, in the same molecule, tend to neutralize each other, and it is only upon their separation in the molecule that the resultant raising of the inductive capacity occurs. This explains what was hitherto inexplicable, namely, the fact that while cyanogen itself has a very low specific inductive capacity, its hydrogen compound, HCN, has one of the highest dielectric constants hitherto found, and that the simple nitriles and normal sulphocyanates have high dielectric constants. The author also studied the dielectric constants of solutions resulting from the combination of various solids, with non-conducting liquids. He found that the volumetric formula advanced by Silberstein for the calculation of the dielectric constants of solutions from those of their components, while roughly approximate for solutions of liquids in liquids, is entirely inadequate when applied to solutions of solids in liquids. Only in one case, that of sulphur dissolved in carbon disulphide, did the results seem to give a clue to the dielectric constant of the solute. In cases where solvents were used with the same solute, the dielectric constants of the mixture did not indicate that the solute exerted a similar influence in each case. This phenomenon points directly to the conclusion that the dielectric constant of a solution is not a simple function of either constituent, but is due to an indefinite compound, i. e., a compound according to variable proportions, resulting from combination of the constituents.

Electrolytic Analysis.—In a Faraday Society paper, published in the January issue of *Electrochem. and Met.* A. Hollard says that the only principle involved hitherto in electrolytic analysis for the separation of elements is that which is based on the successive separation of the metals by gradual increase of the potential across the electrodes, each metal depositing itself at a potential spoken of as the potential proper to the metal. But he thinks that this principle is hardly directly applicable, since the method requires too much time, and that the only applications of this principle which have been made are the separations with very weak currents of copper and silver, of silver and bismuth, and of mercury and bismuth, that is of metals whose polarization potentials are lower than that of hydrogen. If hydrogen is evolved, the deposition of the metal is very slow and will never be complete. The author pronounces the following three principles applicable to electrolytic analysis. The first is "the reduction of the resistance of the bath by suppressing the formation of gas at the anode." This may be done by introducing "a reducing agent into the bath, such as sulphurous acid, which prevents the liberation of oxygen gas by combining with it. This suppression of gas greatly augments the conductivity of the bath; for the same potential applied to the bath the current which passes is much more intense and permits the precipitation of one of the metals on the cathode in a relatively short time." As an example, is given the separation of nickel from zinc. (The author overlooks completely that he has here to do far less with a "reduction of the resistance of the bath," but rather with an entirely new anodic reaction, resulting in a new anode potential.) The same effect may be obtained by using a soluble anode. For instance, in the case of separating nickel from zinc, he deposits nickel upon a platinum cathode, and uses a zinc anode; this is done in a diaphragm cell in which the cathodic compartment contains the mixture of nickel and zinc salts, while the anodic compartment contains a solution of magnesium sulphate. No external source of current is here necessary, since when the anode and cathode are connected by a metallic wire, the whole acts as a short-circuited galvanic cell. The action can then, of course, be explained by Nernst's theory, as is shown by the author. Finally, the author says, concerning such a method, that "there is another secondary phenomenon which does not occur with nickel sulphate, but which is manifest with certain other salts. This can be discussed for the sake of completeness. We mean the migration of the salts in the course of the electrolysis from the cathode (here the platinum electrode) to the anode (here the precipitating metal). This is Hittorf's phenomenon. For each metal, then, it is necessary to find out if it forms a salt which does not show the Hittorf phenomenon, and if it is preferable to work at one temperature more than another, for the losses of concentration round the cathode (and round the anode) vary with the temperature. This method cannot be applied to every class of salt, and so is not general. It cannot be used for copper in particular, the $Cu^{\cdot\cdot}$ ions passing very rapidly to the anode cell." (The author here mixes up two entirely different phenomena, the one being electro-endosmosis or cataphoresis, due to the presence of the diaphragm, the other being the transference of the ions according to Hittorf. On account of the latter, bivalent positive Cu ions will never pass to the anode. Of course, if one electrolyses copper sulphate between copper electrodes without diaphragm, in order to exclude the phenomenon of electric endosmosis, the concentration will decrease at the cathode and increase near the anode. But the latter is the case, not because Cu ions have passed toward the anode, but because more new copper ions are formed from the anode than pass in the same time through any cross-section of the cell towards the cathode.) The second principle depends on the choice of the nature of the cathode, and has to do with the so-called overvoltage required at a given cathode to produce gaseous hydrogen. For a platinum cathode, we can arrange all the metals according to the voltage required to deposit them; they may be grouped into two classes, those in the first class requiring a smaller voltage for deposition than hydrogen, those in the second class requiring a larger voltage. Lead, tin and cadmium are in the latter class. If, however, instead of a platinum cathode, we use a lead or tin or cadmium electrode, the deposition voltage of hydrogen is raised above that of lead or tin or cadmium, respectively; in other words the latter metals can now be deposited without the evolution of hydrogen. As an example, is given the separation of cadmium from zinc, by means of a cadmium cathode. The third principle is the formation of complex salts, an example being Classen's separation of antimony and tin in a concentrated solution of sodium hydrogen sulphide; the tin here passes into the state of a complex anion.

Revolving Cathodes for Electrolytic Analysis.—In the February issue of *Elektrochem. Zeitschrift* H. Paweck makes some remarks on the advantages of using a metal screen cathode for electrolytic analysis. He remarks that in the Stolberg works an amalgamated brass screen cathode is used for the electrolytic determination of zinc, the latter being weighed as amalgam. He then discusses at some length, and with the aid of illustrations various arrangements of revolving electrodes.

Quantitative Analysis.—Notes on quantitative analysis, prepared for the students in School of Mines at Columbia University, are published by E. H. Miller in the November issue of the *School of Mines Quarterly*. The article contains an introduction on some of the analytical applications of the theories of ionization, mass action and solubility product.

Electrochemical Equivalent of Silver.—It is well known that the exact determination of the electrochemical equivalent of silver is of the greatest importance, since this value is one of

the most fundamental figures on which measurements in electrical engineering are based. It is therefore quite natural that the most able scientists of all countries have been interested in careful determinations and re-determinations of this value. In this country Carhart and Guthe have highly distinguished themselves in this direction. For electrochemists we may simply point to the fact that this figure is one of those fundamental figures on which every application of Faraday's law is based (see, for instance, the article of Hering, ELECTROCHEMICAL INDUSTRY, 1903, page 169). The results of former investigators vary from 0.011156 (Mascart) to 0.011195 (Pellat and Leduc). An account of a redetermination by G. Van Dijk and J. Kunst is given in the *Proceed. Akad. Wet.*, Amsterdam, January 21 (and noticed in the Lond. *Elec.*, February 5). The authors used a tangent galvanometer for determining the strength of the current. Owing to the high degree of accuracy with which the constant of the instrument and the horizontal intensity of the earth's magnetic field and its space and time variations may be determined, this method is well adapted for a laboratory which has been built without iron, and in a place where no vibrations or stray currents in the earth are to be feared. The authors adopted Kohlrausch's bifilar method. The cathodes consisted of platinum, being either cup-shaped or in the form of a cylinder ending in a hemisphere. A silver rod served as an anode. Two voltameters were placed in series in order to insure that no irregularities occurred in the deposition of silver. The final mean value obtained from twenty-four measurements was 0.0111818, which the authors believe to be accurate to within one part in 10,000. (The above figures evidently give the electrochemical equivalent in decigrams per coulomb. To get it in grams per coulomb, all the figures are to be divided by 10. It may be remembered that the value adopted by the International Electrical Congress of Chicago, in 1893, was 0.001118 gram per coulomb; i. e., one ampere deposits 0.001118 gram, or 1.118 milligram of silver per second.)

Electrolytic Rectifier.—In the January issue of the *Physical Review*, S. R. Cook gives an account of a series of experiments made to investigate the reasons of the well-known behavior of the aluminium cathode. He used it in a solution of potassium aluminium sulphate and studied the behavior with varying temperatures. He considers his experiments to prove that the apparent resistance of the aluminium anode is not a true ohmic resistance, but a "resistance of transition of ions" manifesting itself in a counter e. m. f. There is formed on the aluminium surface a film either of normal aluminium hydroxide, $Al_2(OH)_6$, or, as he believes more probable, of aluminium oxide, Al_2O_3, with water of crystalization in that part of the oxide which crystallizes. This film is a very poor electric conductor, and its formation prevents the anions from reaching the conducting surface of the anode and thus discharging. When the aluminium is the cathode, hydrogen is developed; the cation finds access to the metallic surface of the aluminium plate and hydrogen is set free between the film of alumina and the metallic aluminium, thus separating the two surfaces and exposing the metallic aluminium to further action of the cations. As long as the applied e. m. f. remains below a certain critical value which depends upon the temperature, the film formed upon the aluminium anode is very hard, whitish, compact, non-crystalline and apparently insoluble in the electrolyte When, however, the applied voltage is greater than the critical value, the film changes from a white non-crystalline substance to a dark crystalline substance at certain parts of the plate. In crystallizing, free metallic surfaces are exposed to the action of the anions which now may be discharged and current can pass. The value of the critical pressure, and also the counter e. m. f. depend upon the temperature. The critical e. m. f. for one degree is approximately 47 volts, and for 48° only 22 volts. The counter e. m. f. increases with the increase of temperature.

Electric Resistance Furnace for the Laboratory.—In form of a reply to the article of Guntz (abstracted in the Synopsis, January, 1904, p. 29) W. C. Heraeus gives in the *Jour. de Phys. Chim.*, January, some details of his own laboratory furnace in which, as will be remembered, very thin platinum foil is used for the heating coil. His furnaces do not consume considerably more current than that of Guntz, but some power losses cannot be avoided in a furnace which shall be suitable for general laboratory work. The heating tube on which the platinum foil is wound has only a small mass which assumes nearly instantaneously the temperature of the platinum foil, and follows immediately all changes of its temperature. This allows rapid and exact regulation of the temperature.

The Constitution of Salt Solutions.—It becomes clearer every day that the ideas on the constitution of salt solutions, as they were generally held on the basis of the electrolytic dissociation theory, cannot be strictly correct, as they are too simple. Hittorf had already shown in 1859 that the salt $CdCl_2$ contains in solution besides the simple ions Cd (bivalent positive) and Cl (monovalent negative), also complex ions of the general formula $(CdCl_2)n\ (Cl')m$. The possibility of the formation of such complex ions has later been mostly overlooked, although Arrhenius, Abegg and Bodlaender and Biltz were led to similar conclusions. In this connection a paper by R. Abegg, based on experiments of S. Labendzinski, is quite interesting. It shows that such complex ions exist even in simple solutions to a considerable degree. One of the main results is that the old disagreement between theory and practice in the case of Ostwald's law for the relation between conductivity and dilution may now be explained. On the other hand, the great simplicity of ideas which was one of the beauties of the dissociation theory, is to be given up. The paper of Abegg is published in *Zeit. f. Elektrochemie*, January 29.

BATTERIES.

Action of Light Upon the Formation of Accumulator Plates.—Some peculiar observations, which, however, are evidently of scientific interest only, are recorded by D. Tommasi in *L'Eclairage Elec.*, February 13 (also in Lond. *Elec. Rev.*, February 12). In short, he found that the negative plates of an accumulator form more rapidly in light than in the dark, while the positive plates form more quickly in the dark than in the light, other things being equal. Also, the positives formed in the dark are characterized by a dark-brown appearance, those formed in the light being of a reddish-brown color. This difference of shades persists during several charges, but eventually disappears entirely. Thus the reddish color of the positives which have been exposed to the light becomes darker and darker, until it attains the brown tint of the positives which have been formed in the dark. The capacity of an accumulator, whether charged in the light or in the dark, was found to be practically unchanged.

Accumulator Traction.—It is estimated that of all storage batteries, now manufactured, 75 per cent are used as stationary batteries in electric central stations and sub-stations. The increased interest in automobilism, and the obvious advantages of the electric automobile have created a new and promising field for a light battery. On the other hand, for traction on rails, the storage battery has not succeeded in holding its own, in spite of a great many attempts. Some data given in the *Elek. Zeit.* of Feb. 11, by P. Lanino on storage battery traction of some Italian lines, show that the system was there a success from a technical and especially from a financial standpoint. On the line from Milan to Monza the cost of operation was 16.25 cents per car kilometer (the cars having a weight of 58 tons), the energy consumption was 65 watt hours per ton kilometer, the cost of maintenance of the plates was 7 cents per ton kilometer. The operation of the system was discontinued since it was not elastic enough, the traffic being too heavy and not enough motor cars being available on holidays. On the line from Bolgna to San Felice the cars had a weight of 15 tons, and could carry 75 passengers. The cost

of maintenance of the battery was 6.075 cents, and the total cost of operation 11.15 cents per train kilometer. In spite of the results which were good beyond expectation, the accumulator system was discontinued partly on the desire of some influential officials of the company, and partly because the service was not sufficiently elastic, as in the other case.

Edison Nickel-Iron Storage Battery.—W. Hibbert's paper, which we have already noticed, was recently discussed at length before the (British) Inst. Elec. Eng. A full report is given in the *Lond. Elec.*, February 5. W. Hibbert mentioned the recent improvement due to the use of twice as many nickel-plates as iron plates, and gave the curves for the new cell which were already published in our January issue, p. 37. J. A. Fleming gave an account of the tests which he has made with the older type, and remarked that Janet, Hospitalier, Finzi, Hibbert and himself, had all practically obtained the same results. E. J. Wade discussed the probable reasons why the voltage drops gradually during discharge, the curves for the Edison cell closely resembling those of a lead cell. Yet, the reason cannot be exactly the same in both cases. He thinks that in both cases the first rapid fall is due to the peroxide products in the cell, and the final fall to the specific resistance of the active material, while he attributes the intermediate fall to slight variations in the concentrations of the electrolyte. (This explanation seems questionable. Concentration changes will develop in the pores of both plates of the Edison cell, but the concentration will increase in one plate and decrease in the other, and if we keep on with the same rate of discharge, we should expect that soon a stationary condition would be reached in which further increase and decrease of concentration would be annihilated by diffusion. It can be shown that the variation of the e. m. f. proper, due to these concentration changes, is small. On the other hand, the resistance of the active material must change continually and quite considerably. The resistance is quite a complex function, since the oxidation or reduction of the active material here proceeds from the outside to the inside of the briquettes, and the resistance is not only a function of the metallic particles in the briquettes, but also of the dilute or concentrated electrolyte in the pores.) H. L. Joly gave some interesting results of tests which had been quite disinterested and uninspired. He did not know of any cell in which Peukert's coefficient is so low, and came to the conclusion that it is perfectly safe to take it at 1.1, which is the lowest figure on record. The results of his charging tests are given in Fig. 1. Curve A shows the rise in p. d. when charg-

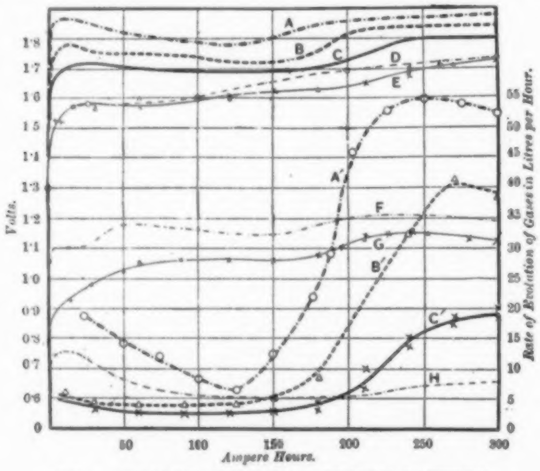


FIG. 1.—CHARGE CURVES OF EDISON BATTERY.

ing at 100 amperes, curve B when charging at 60 amperes, and curve C at 30 amperes. Immediately under these three curves are two others, that marked D showing the rise of e. m. f. corresponding to a charging current of 100 amperes, and that marked E to charging currents of 60 and 30 amperes. Now, it will be seen that the p. d. remains practically constant after the cell has received 250 ampere hours, but the e. m. f. continues to rise, and this led him to think that the e. m. f. was not a true indication of the state of affairs. Moreover, the curves A', B', C' which represented respectively the rate of evolution of gas, when charging at 100, 60 and 30 amperes, in liters per hour, showed a downward tendency after the 250-ampere-hour point. This was probably due to a diminution in the quantity of free H_2O in the electrolyte, and everything tended to show that the cell was fully charged when it had received 250 ampere hours, and it was, therefore, unnecessary to go as far as 300 ampere hours. The curve F represents the p. d. between the iron electrode and the case at the 100 ampere rate, G, the p. d. at the 30 and 60 ampere rates, and H showed the variation of p. d. between the nickel electrode and the case at all three rates of charge. Fig. 2 shows the comparative behavior of the plates tested by means of an auxiliary electrode; cadmium was first tried, but the use of the container itself gave more reliable figures. This method showed a drop on the negative electrode, and a rapid recovery, at the same time as the p. d. dropped on the nickel plate and settled at the lower level. W. R. Cooper and W. H. Patchell also participated in the discussion.

In *L'Eclairage Elec.*, February 6, R. Jouaust publishes a long article on the Edison accumulator, giving nothing new, but summing up the existing extended literature quite concisely and fairly, and dealing at some length with the chemistry

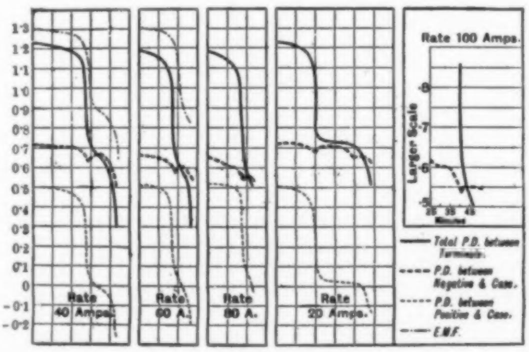


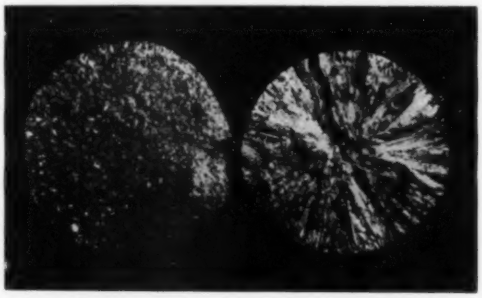
FIG. 2.—BEHAVIOR OF INDIVIDUAL PLATES AT END OF DISCHARGE.

of the subject. He mentions that in searching for a new and light accumulator, Krieger, Michalowski, Gahl and Jungner had made nickel oxide and an electrolyte of sodium hydroxide the subject of patents, but "of all these cells only the last one was followed up by an attempt at realization." "The Jungner battery has never been the object of official tests in France, and the results obtained by Schoop, and published in *Elek. Zeit.* (see ELECTROCHEMICAL INDUSTRY, vol. 1, 1903, p. 465) do not seem to be favorable to that cell, the capacity of which would be only 18.6 watt hours per kg. for a discharge rate of 1.2 watts per kg." His final conclusion on the Edison battery is that, in spite of its relatively low efficiency, it will apparently render great services in all cases in which one needs a battery of high discharge rates, especially on automobiles and submarine boats; and this is the object for which it was designed by its inventor.

Jungner Battery.—Some data on the Jungner battery which is being developed by the Koelner Akkumulatoren Werke, Gottfried Hagen, are given by H. L. Joly on the basis of information received from M. U. Schoop of that company, in the January issue of *Electrochem. and Met.* In the construction of the Jungner plates sheet steel 2 mm. thick, nickel-plated and perforated, with the burrs retained, is folded on itself so as to form pockets. The perforations are arranged so as to leave solid metal where the sheet is folded. Two, three, or

more pockets are placed side by side, and clipped top and bottom by nickeled steel bands, which may be soldered, and are brought together to a connecting bar, provided with a screw terminal, upon which they were at first fixed by screws. This experimental construction has, however, been improved. At present removable airtight lids of stamped steel, with rubber joints and valve are used. The following results were obtained by Schoop with a cell 273 mm. high (with terminals 303 mm.), 77 mm. wide and 86 mm. long, the total weight being 3.106 kilograms. For a discharge rate of 20, 10 and 1 amperes, the capacity was 30, 39.5 and 48.0 ampere hours, and 30.9, 44.24, 57.6 watt hours. (That is, for the low discharge rate of ampere, a capacity of 18.5 watt hours per kilogram, or 8.4 watt hours per pound, which is far below that of the Edison cell.) It is said that the capacity obtained at 20 amperes, with a more recent cell (of the same weight?) was 50 ampere hours. Schoop and Jungner have succeeded in making a gelatinous alkaline electrolyte for their cells. The priority question between Edison and Jungner is discussed, and an opinion of G. von Knorre is given, who expresses himself strongly in favor of Jungner.

Structure of Zinc Electrodes.—An interesting example of the influence of the structure of zinc on the action of zinc electrodes in primary cells is described by R. Job in the *Iron and Steel Metallurgist* of February. The zincs of some gravity cells, used in connection with railway track signals, had worn away very rapidly in service, and had averaged only about one-third of the life usual under the given conditions. As the metal dissolved, relatively large portions of the zinc became loosened and dropped upon the copper sulphate crystals beneath, and thus reduced the efficiency of the cell. The zinc, upon analysis, was found of good quality, but upon examining the structure, a very large, coarse granular form was found due to pouring the zinc into the mould at a relatively high temperature. The fracture is shown to the right of the adjoining illustration. Some of the same zinc was then taken,



STRUCTURE OF BATTERY LINES.

melted and poured into the mould at a fairly low temperature, giving the structure represented by the fracture to the left in the illustration. Upon putting these zincs in service, under the same conditions as previously, no scaling off occurred, and the zinc wore away gradually, giving the normal life. The defective service of the coarse-grained zinc is easily explained by assuming that under the electrolytic action the liquid penetrated along the surfaces of the crystals, and, as action progressed, gradually dissolved the metal along such surfaces and thus finally resulted in the scale. In the fine-grained zinc, no such action was possible, owing to the small size of the crystals. This is another example illustrating the fact—which is often not sufficiently appreciated—that chemical composition is not everything, the structure playing often an important part in the application of metals to pracical uses.

FRANKLIN INSTITUTE.—On March 3, Mr. William M. Scott, electrical engineer of the Cutter Electric & Manufacturing Co., of Philadelphia, will deliver a lecture on circuit breakers, and Mr. J. Hart Robertson on the diaphragm storage battery.

Correspondence.

MERCURY CATHODE CELL.

TO THE EDITOR OF ELECTROCHEMICAL INDUSTRY:

Sir—Your issue of December, 1902, has just come to my notice, containing therein, on page 132, a description of my electrolytic cell. To the casual reader, Dr. Scholl gives an unfavorable impression by his analysis, which is in part due to his not having read the drawings correctly. The wires shown, for moving the sweep do not pass through the electrolyte at any point and were never designed to do so, although the cut shown seems so to indicate. These wires run under the inclined planes, which serve to direct the amalgam into the discharge pipes.

The objection he makes to the protection of the amalgam in the traps is of very small importance, if of any, as the reaction in a small pipe is inconsiderable to that of the main body of mercury. By the auxiliary circuit they are equally protected. In fact the amalgam can be enriched after reaching the pipe, if it comes in poor enough.

The cell was not designed from theoretical or laboratory conditions alone, but is the outcome of practical experience.

ARTHUR E. TRUESDELL.

Pittsfield, Mass.

AMERICAN ELECTROCHEMICAL SOCIETY ELECTION.

TO THE EDITOR OF ELECTROCHEMICAL INDUSTRY:

Sir—In common with most of the directors of the American Electrochemical Society I signed a petition for a constitutional amendment, making the president, vice-presidents and managers ineligible for re-election. I must therefore decline to be a candidate for re-election to the office of vice-president, for which, I am officially informed, I have been nominated.

At the same time, in view of the very handsome vote which my friends have cast for me in nomination for the presidency of the society, and of the fact that the board of directors are not endorsing any one for that office, I announce myself as a candidate for the presidency.

HENRY S. CARHART.

Ann Arbor, Mich.

Book Reviews.

KALENDER FUER ELEKTROCHEMIKER, Sowie Technische Chemiker und Physiker, 1904. By Dr. A. Neuburger. Published by M. Krayn, Berlin. Price, $1.35.

The "Kalender fuer Elektrochemiker, etc., 1904," shows a vast improvement over its edition of 1903, and it is gradually working itself into a book which will be a "vade mecum" to the chemist and electrochemist. Many of the tables have been revised and others greatly enlarged, yet there is in more than one case margin for further improvements. The tables on the "minima potentials of decomposition" show a decided improvement over last year's edition, also many of the other tables show signs of improvement. A new logarithm table has been added to the mathematical section, and Dr. Neuburger has included the fundamental formulæ for differential and integral calculus, which electrochemists can make good use of. Dr. Neuburger would do well to omit the first 80 pages, which are inserted for diary, or fill them up with more important matter. Citations are in many cases missing, and when mentioned are not fully enough quoted, to make further use of. In the preface Dr. Neuburger requests those interested in the science, to give him advice, as to where the calendar is open for improvement, and how it might be improved. We hope that all electrochemists, each in their special branch, will help the editor in his effort to perfect this book.

Iron, Steel, and Other Alloys. By Henry M. Howe, Boston: Sauveur & Whiting; 457 pages. Price, $5.00.

The preface states that this work is intended to give to technical students and practitioners a systematic account of the metallography of iron, and more particularly to expose to them the present "solution" theory of the constitution of iron, and of alloys in general. In pursuance of this aim, the chapters of the book deal with the following subjects: Cooling Curves, Freezing-point Curves, Constitution of Binary Alloys, forming no definite chemical compound; Constitution of Alloys forming definite chemical compounds; the Metallography of Iron and Steel, the Heat Treatment of Steel and Cast-iron, the Phase Rule, and closes with chapters on Progress in the Manufacture of Iron and Steel from 1880 to 1900, the Blast Furnace, and Metallurgical Gas Furnaces.

The first sentence of the preface is an apology for the heterogeneousness of the book, and in this respect the author forestalls criticism of its greatest defect. In order to express accurately in the title the full scope of the work, the author must needs have copied after the title pages of a fifteenth century treatise on theology, and given as a title a symposium of the chapter headings.

However, all that is in the book is good, though of different degrees of excellence. The chapters on cooling curves, freezing-point curves, the constitution of the two classes of alloys, and the phase rule are carefully, painstakingly and lucidly written, in a manner which will make the subjects clear to anyone who will carefully study the text. The chapter on the metallography of iron and steel is exhaustive of the subject, and of the reader. It is too painstakingly elaborated, with consequent loss of force and clearness, and, in many cases, with no sharp line drawn between the facts of the subject and conjecture. The coining of such terms as *Aeolic* and *Hypo-aeolic* steels is a misdirection of energy, for such terms are too pedantic and too little expressive to find any enduring place in the literature of this art, and still less in its working nomenclature. This chapter is clearly overdone. The subject of the heat treatment of iron and steel is more satisfactory, where it touches on the facts of the subject, and more practical in its bearing. It contains much valuable information for anyone who has to study or handle iron or steel, its sixty-four pages giving a thorough treatment of the subject in a scientific manner.

The three concluding chapters contain much information which would supplement and bring up to date our text-books on iron and steel manufacture, together with some elementary presentations of the principles of the subject which are too brief to be of much use to anyone except the most casual, untechnical reader. Taken together, they are a sort of metallurgical *olla podrida.*

There is one promise in the title, brief as the latter is, which is not fulfilled in the book; viz., the "Other Alloys." One would expect, from that, a systematic discussion of the constitution of other metallic alloys than those contained in iron and steel—(such a treatise is badly needed, and a large amount of scattered material for its compiliation exists in the recent volumes of our scientific journals)—but, alas, there is to be found in the book only an incidental reference to a few of the non-ferrous alloys, and the needed treatise on the "Other Alloys" is still to be written.

As we may have appeared harsh in indicating the shortcomings or defects of Prof. Howe's book, we repeat again that a great deal of valuable information for anyone interested in the study of iron, steel or alloys, is contained in the work, it is beautifully printed and illustrated, and can be heartily recommended as well worth reading, and studying.

Storage Battery Engineering. By Lamar Lyndon. New York: McGraw Publishing Company. Price, $3.00.

The appearance of this book has been welcomed by many who have to do with storage batteries. It fills a need in the literature on the engineering practice of the lead cell. The chapters on boosters are specially noteworthy, since it is there the first time that the construction and use of boosters has been fully described in a book on storage batteries. This is creditable, since booster systems have been developed to a high degree of perfection, especially in this country. The manner in which the author deals with the subject shows distinctly his experience in this line.

Concerning the theory of the lead cell there are some points to which exception might be taken. For example, it is generally believed that the reaction in the lead accumulator is represented by the equation

$$PbO_2 + Pb + 2H_2SO_4 = 2PbSO_4 + 2H_2O$$

not only for very small current densities, but also for those used in practical work, and that the changes in the acid density during charge and discharge may be derived from this formula. Of course it must here be borne in mind that the hydrometer does not show the average specific gravity of the total electrolyte in a cell, since the exchange of acid by diffusion between the pores of the plates and the outside electrolyte is not instantaneous. It may be recalled that about a year ago Dr. Sieg, in his German book on the lead accumulator, published measurements which appeared to be contradictory to the above formula. Afterwards, however, Mr. M. U. Shoop published an article in the *Electrotechnische Zeitschrift*, showing that if one takes into account that the exchange of acid requires some time dependent upon the type of the plate, Dr. Sieg's results are not contradictory to the above formula.

In the chapter on the Planté formation the author has carefully collected patents as the only literature on this subject. Of course, this cannot give a good idea of the useful processes, since for this branch of storage-battery engineering, it is at least as true as for others, that almost all the patents are worthless. The few experiments published recently in Germany and referred to by the author, do not give any better idea about the value of a method of formation, as they do not show results for chemicals in practical use as forming agents. Therefore, this chapter cannot be considered quite satisfactory, although allowance must be made for the difficulties in its preparation.

Local action of the plates, both positive and negative, is mentioned. To explain the latter, the voltage at which hydrogen is developed at different metals should be taken into account, as is done, for instance, by Dolezalek in his book. The difference of the hydrogen developing voltage or "overvoltage," as it is called, of lead and metallic impurities accounts completely for all phenomena of local action on the negative plate. There is no local action between grid and spongy lead unless the first consists of impure lead, and the formation of spongy lead from the grid itself does not prevent local action.

But these theoretical errors, which are very few, do not lessen the value of the book, particularly as its subject is storage battery engineering, while the theory of the accumulator is not its most essential part. As a whole, the book must be called a very useful addition to our literature on the lead accumulator.

Current Notes.

Electrometallurgy of Iron and Steel.—We are informed that the German patent of M. Gin (whose process was described by Mr. Bennie in our issue of January, 1904, page 20) has been sold, and the process will be exploited upon an industrial scale at Plattenberg, within about four months. We are also informed that Messrs. Keller, Leleux & Cie (whose process was described in our issues of January, 1903, p. 162, and August, 1903, p. 470) are contemplating a large works in this country, to install and operate electric furnaces for the production of steel. The industry moves apace.

ZINC WHITE.—In a London daily paper it is stated that Sir William Ramsay and Prof. E. Ellershausen have succeeded in obtaining, by a new process invented by Prof. Ellershausen and Mr. R. W. Western, zinc white worth £30 ($146) a ton from the refuse heaps of the Hafua mines in Wales. Throughout Wales there are scores of mines, closed because it does not pay to work them. All these mines have miniature mountains of debris, or "tailings," at the surface. There are millions of tons of this unregarded material, which mine owners have hitherto looked upon as an unavoidable nuisance. White lead frequently takes the place of zinc white, and very little zinc white is made in Great Britain. Wales found the process of making it from "spelter"—which itself costs £21 ($102.20) per ton—too expensive to leave a fair margin of profit. Hence, the present dreary succession of abandoned mines, some of them holding machinery worth many thousands of pounds. But zinc white is indispensable in certain industries; thus England imports annually from Germany, Belgium, and the United States some 200.000 tons. "By the new process the expensively obtained spelter is entirely dispensed with. The zinc white is taken direct from the ore, which costs but a tenth the sum; more, as Sir William Ramsay and the other professors showed, the very refuse of the mines can be made to yield a substantial amount of the material. From about 15 tons of the rubbish 1 ton of zinc white can be extracted. As the zinc white was rapidly evolved from the crude mineral without the elaborate and roundabout methods of the spelter system, Sir William Ramsay exclaimed, with a smile of surprise, 'A pretty process, indeed!' 'I do not see why a new era of prosperity should not dawn for Wales,' the distinguished scientist remarked."

CARBURETED AIR LIGHT.—A recent consular report states that Dr. Hugh Marshall, of Edinburgh, has invented another method of using carbureted air for lighting. It is an improvement upon the form of lamp devised by M. Naum Notkin, of Moscow, in which carbureted air was obtained by employing paper pulp saturated with gasoline to produce the vapor required. In this Notkin "gravity" lamp the carbureted air, being denser than air itself, flowed from a higher to a lower level, instead of ascending like coal gas, and could therefore be poured from one vessel to another, like a liquid. In the Marshall lamp the necessary current of air through the carbureter is not maintained by the effect of gravity, but by means of the draft from the lamp chimney. It is thus possible to have the body of the lamp below the actual burner. To reduce the manipulation necessary with such a lamp when used for incandescent lighting, Dr. Marshall has invented a form of burner tube, which is sunk axially into the body of the containing vessel, and which enables the user to regulate the mixture of vapor and air to a nicety by simply rotating the tube in one direction or the other. The new method of using carbureted air has been applied by Dr. Marshall to various types of lamps —table and portable hanging, basket, and also in lantern form for outdoor lighting. These show a brilliant incandescent light, without any liquid or wicks being used, and are free from smell or smoke. Dr. Marshall claims also that carbureted air can be supplied all over a house without danger or complicated processes, and that the gas can be applied to other purposes than lighting, such as for heating and motive power.

THE USE OF CAUSTIC POTASH IN ELECTROPLATING SHOPS.

The success of an electroplating operation depends, not only upon the use of the proper solution and current density, but just as much on the cleanliness of the surface of the article which is to be plated. This surface should be absolutely free from all grease and dirt. While this is a general rule, it applies with special force to nickel-plating, since an electrolytic nickel deposit has always some tendency to peel off (if proper precautions are not taken) and since the chemical nature of the ordinary solutions used in nickel-plating, is not such as to have a dissolving action on grease. But what applies to nickel, applies more or less to every plating process, and it may be correctly stated that grease is one of the worst enemies which every electroplater has to meet. This is, of course, well known, and every practical electroplater knows how dangerous it is to touch the article to be plated with the hands, before it is placed in the plating bath, since a very thin film of grease, thus imparted to the surface, would prevent the full success of the plating operation.

The good condition of the bath, in which the article is first placed, in order to free its surface from grease or dirt, is therefore of just as much importance as the plating bath itself. For the removal of grease, a caustic soda solution is often used, but caustic potash is now coming into more extended use, since its action is more rapid and powerful than that of soda. Besides, the soap formed by the action of the caustic potash upon the grease is very easily soluble in the solution, so that all grease spots are easily removed, and the surface is perfectly cleaned.

If a caustic soda solution is used, the articles are being cleaned slowly, and, in many cases it is necessary to use other cleaning ingredients after the article has left the cleaning bath. This is not necessary with caustic potash. It is stated that a large concern recently replaced a 20° Baumé solution of caustic soda by a 3° Baumé solution of caustic potash, and the result was that the cleaning process was much quickened, improved and, besides, cheapened.

The Roberts Chemical Co., of Niagara Falls, N. Y., make a specialty of supplying caustic potash to electroplaters, putting it up either in solid or liquid form, the latter in carboys, because some platers find it more convenient in this form.

SILICON-COPPER IN THE BRASS FOUNDRY.

In our issue of October, 1903, page 498, we noticed briefly the plant of the Cowles Electric Smelting & Aluminum Co. at Lockport, N. Y., which contains much of historical interest with respect to electric smelting, while at present the main output of the plant is mostly silicon-copper. In the following the use of silicon-copper in the foundry for producing the highest grades of brass, copper and bronze castings will be discussed, but we may first say a few words on the method of its manufacture. In an electric furnace, principally of the same type which was used by the two brothers, E. H. and A. H. Cowles in their early experiments, the original charge is melted to produce an alloy of silicon and copper; to bring this alloy afterwards to standard composition, it is remelted with such additions as may be necessary.

Every foundryman knows the difficulties involved in the manufacture of pure copper castings. This difficulty is due to the fact that cuprous oxide is dissolved in molten copper and the obvious remedy is to add a reducing agent which reduces the cuprous oxide to metallic copper. Phosphorus has been found to meet this purpose to some extent, but silicon-copper is more active in clarifying, refining, hardening and strengthening copper and its alloys. The reason of the action of silicon-copper is that the combination heat of silicon with copper is very high; the silicon therefore takes away quickly the oxygen from the cuprous oxide, to form silica; silicon itself is, of course, unsuitable as an addition, it is therefore added in the form of silicon-copper.

There is no violent ebullition when silicon is added to copper or copper alloys—which cannot be said of phosphorous. The silicon-copper can be introduced without the slightest danger of explosion.

A pound and a half to two pounds of silicon-copper is required for every one hundred pounds of melted copper, to produce castings clean, solid and free from blowholes, swellings, etc. Its being placed in the crucible before pouring assures a uniform fluidity and an instant reduction of the oxide of copper. The method is of great importance for copper used for

electrical purposes. Large electrical conductors, so much in demand at this time, can be cast and marketed at a far lower figure than if worked or forged from rolled copper.

Silicon-copper is also extremely useful in the manufacture of high-grade castings in tin-bronze and brass. In tin-bronze mixtures where there is a large percentage of copper, silicon-copper to the extent of from 4 to 8 ounces only is required to 100 pounds of the bronze, in order to produce perfect deoxidation. Dullness or sluggishness in brass and tin-bronze mixtures is often caused by the gases due to the oxides in the metal. The addition of a very small amount of silicon-copper, say from 2 to 4 ounces per 100 pounds, expels the gases and reduces the oxides to metal. The fluidity of the mixture is increased to a marked extent, thereby enabling one to make sharp castings.

The copper-silicon, made by the Cowles Electric Smelting & Aluminum Co., is put up in ingots weighing about 14 pounds each. The alloy is exceedingly brittle, and can be readily reduced to small pieces, in order to add it to the metal to be treated after the other ingredients are in the crucible. When added to pure copper, the silicon-copper should be placed in the crucible just before taking from the furnace. The contents should be stirred thoroughly and skimmed well before pouring.

Besides silicon-copper, the Cowles Electric Smelting & Aluminum Co. make several valuable aluminium alloys, among them aluminium alloy No. 1, for castings, containing about 90 per cent aluminium, and nickel-aluminium, which is one of the strongest and best light alloys on the market, being recommended especially for automobile gear and motor cases, etc.

FERRO-SILICON MADE IN THE ELECTRIC FURNACE.

Ferro-silicon made in the electric furnace can now be supplied as a sound and solid alloy, containing 50 per cent of silicon, without any tendency to disintegrate. The following six principal advantages are claimed for it over the ordinary alloy made in the blast furnace: greater purity; economy in cost of carriage, storage, and handling; smaller quantity to produce the same silicising effect; less cost per unit of silicon; less reduction of heat of molten metal on the addition of the ferro-silicon, and less time required for the amalgamation of the ferro-silicon with the molten metal, and consequently less consumption of fuel.

The following two tables give the typical analysis of the blast furnace alloy, in comparison with the electric furnace alloy:

Typical Analysis of Blast Furnace Alloy.		Typical Analysis of Electric Furnace Alloy.	
Silicon	10.55%	Silicon	51.80%
Iron	83.16%	Iron	46.13%
Carbon	2.36%	Carbon	.15%
Manganese	3.86%	Manganese	.08%
Sulphur	.03%	Sulphur	.003%
Phosphorus	.04%	Phosphorus	.057%
		Aluminium	1.61%
	100.00%		99.830%

A comparison between these figures is instructive. If it be required to add to any furnace charge as much silicon as is contained in 1 ton of blast furnace alloy, the impurities added at the same time are given by the corresponding percentages of one ton. But if the same quantity of silicon is required, and electric furnace alloy is used, the quantity of alloy needed is one-fifth of a ton, and therefore only one-fifth of the percentages of the impurities are added to the charge. Thus, we add, if using:

Blast Furnace Alloy.		Electric Furnace Alloy.	
Carbon	2.36% of 1 ton	Carbon	.030% of 1 ton
Manganese	3.86% " "	Manganese	.016% " "
Sulphur	.03% " "	Sulphur	.0006% " "
Phosphorus	.04% " "	Phosphorus	.0114% " "
		Aluminium	.322% " "

The extra amount of iron added in the first case, which is regarded by some users as costing nothing is an expensive economy, when confronted with the disadvantages inseparable from the introduction of its accompanying impurities, while, as regards price, silicon for silicon, there is no difference between them. Electric furnace alloy costs about five times as much as blast furnace alloy, and contains about five times as much silicon.

STEEL.

When used in the manufacture of steel, whatever the process employed, the first effect of the silicon is to combine with any oxide of iron remaining in solution in the bath, and thus to prevent to formation of "red short" metal. Silicon thus added operates much more effectually than silicon left over from insufficient oxidation, whether by blast or otherwise—hence the desirability of using the purest possible alloy.

As it is silicon which operates to prevent oxide of iron remaining in the bath, it is preferable that whatever is added for this purpose should consist, as far as possible, of silicon, and nothing else.

The combustion of each kilogram of silicon produces 7830 units of heat, i. e., each kilogram of silicon raises the temperature of 100 kilos of molten metal by about 300° Centigrade. White pig iron is not easily refined without ferro-silicon to serve as combustible.

Electric ferro-silicon is practically suitable for the basic process, where it is added as the carbon is being boiled down, and where the metal is poured as rapidly as possible. Therefore, very little carbon being introduced, the operation of decarbonizing the steel is scarcely interfered with, the process is not prolonged, and the fuel saved.

On the contrary, if blast furnace ferro-silicon be added, considerable carbon is introduced and also other impurities at a stage when in this process it is too late to get rid of them by combined boiling, itself involving greater fuel consumption.

IRON.

The operation of remelting cast iron tends always to increase the amount of combined carbon, and to reduce the graphite, thus rendering the iron whiter and harder at every melting.

The presence of silicon, which has greater affinity for iron than carbon, corrects this tendency, because it prevents the iron dissolving the carbon, and thus enables it to retain and even recover the softness due to the presence of a large proportion of graphite.

Generally speaking, the effects are: to render the casting more liquid, and therefore to take the moulds more sharply—to render it sounder—to improve the quality of the iron, largely converting white iron into gray—to render it possible to use cheaper iron and more scrap—and when sufficient in quantity to increase the strength of the casting.

All these effects are due to the contained silicon. Therefore the more silicon there is in the alloy used, the greater is its effect.

Concerning the superiority of the 50 per cent electrolytic over the 10/15 furnace-made ferro-silicon, the results of one of the largest steel casting companies in America are of interest.

In the ordinary run of steel scrap, the practice is to use from 10 to 12 pounds of the silicon, to a ton of the metal charged in the furnace. When the metal is of unusual good quality, this amount can be reduced. That, of course, is left to the judgment of the melter.

The advantage of this high grade silicon over the 10 per cent to 12 per cent is that it is not left in the furnace any length of time. The charge is made by throwing same right into the bath, and the heat is immediately tapped, the time consumed between time of charge of silicon and running of heat, being about ten minutes.

The low grade silicon is banked on the inside of the charging door to thoroughly heat same, then pushed into the bath, even then causing it to chill more or less. It also takes longer

to dissolve, thus causing a large per centage of the silicon to be burnt out. The high grade silicon also acts in the metal like aluminium, causing the metal to be very quiet, especially when the steel scrap is of a very rusty nature.

The electric ferro-silicon alloy can be obtained from Messrs. E. J. Lavino & Co., of Philadelphia, who have arranged to always carry a stock of the metal in this country.

METEORIT

In these days of extended investigations on the properties of alloys it has been found that comparatively very small additions to a metal may give it new and highly desirable properties. While most of the work has been done in connection with the iron and steel industry and an enormous amount of experimental work has been done in this line with all the different rare metals, yet other metals have not been neglected, and various experimenters have tried to attribute to aluminium properties which the pure metal does not possess, without destroying its good characteristic features. In fact, experiments in this line have gone on all the time since the beginning of the aluminium industry.

Several years ago the properties of an alloy of aluminium with magnesium, called magnalium, was much talked of, since it was claimed to be very easily machined. The following information relates to another new alloy, meteorit, which is the invention of Mr. Walter Ruebel, of Germany. We are indebted for this information to Mr. E. May, 74 Beaver Street, New York City, who is interested in introducing this alloy in this country.

Meteorit is essentially aluminium, with an addition of 4 to 7 per cent of phosphorous, but the details of the method of manufacture are kept secret. It seems that meteorit has already found application in various German manufacturing plants, especially shipbuilding works, automobile factories, breweries, manufactories of articles for fire departments, bicycle works, manufactories of electrical apparatus and optical and geometrical instruments.

The following claims are made for meteorit. It makes an excellent casting, milling cutter and planing tools leave a smooth surface. It files clean and clear. It can be cast over and over again without losing its good features. The casting stands a good hammering, whereby it becomes of such density and resistance as to be used for astronomical and mathematical instruments. It is especially suitable for bearing material. It is suitable for rolling and drawing purposes, and can be hammered to the thinnest foil without cracking. A good polish can easily be applied. In general it can be very easily machined. It is stated that it may be easily soldered, and that it receives, without difficulty, an electroplating deposit.

Meteorit has the same low specific gravity as aluminium, viz., 2.6 to 2.8, and the softest meteorit wire (No. 1) has about the same electric conductivity as pure aluminium; namely, 62, against 100 for pure copper, and 88.9 for commercial copper.

Another important property of meteorit is its high resistance against chemical reagents. It is not in the least effected by nitric acid and organic acids, as acetic acid, regardless of its concentration, nor by the fumes of these solutions. It is also stated not to be attracted by neutral salt solutions, even if highly concentrated, nor by ammonia solutions. For rolling purposes meteorit is stated to be very excellent, and sheets have been made of 3 mm. to 0.06 mm. in first-class quality, very hard, as well as soft, the latter being intended for further manufacturing in tubes and for cutting and stamping.

INDUSTRIAL NOTES

Bulletin 147 of the C. & C. Electric Co. gives a list of some users of type MP generators and motors, and some of the principal installations of C. & C. generators and motors. Among them are quite a number of electrochemical and metallurgical plants.

The Vereinigte Fabriken fuer Laboratiums bedarf, of Berlin (formerly Max Kaehler & Martini, and Dr. Peters & Rost), announce that they are soon to open a sole agency at New York City, under the firm name of Laboratory and School Supply Co. The chemical laboratory to be exhibited at St. Louis by the Department of Education of the German Government, and the equipment of the Agricultural Experimental Station exhibited by the Department of Agriculture of the German Government, have been completely furnished by the above-named firm.

A convention of the branch managers, department managers and salesmen of the H. W. Johns-Manville Co., of New York City, was in session from February 15 to February 20. Representatives to the number of about thirty-five from all parts of the country were present. The delegates first met in Hartford, where they were the guests of the Johns-Pratt Co. The object of the convention was to bring all branches into closer touch with each other, and to give opportunity for a general discussion of the various lines of manufacture of the company.

THE LUNKENHEIMER Co., of Cincinnati, makers of superior brass and iron steam specialties, report that owing to the growing demand for their specialties, they have again greatly increased their facilities, and are now in position to guarantee reasonably prompt shipments. They also report, through their foreign branches, an increasing export demand for their specialties and inform us that they will shortly place some new specialties upon the market, which will be contained in a very complete catalogue, to be issued in the course of a few months.

THE GOLDSCHMIDT THERMIT Co. has been incorporated under the laws of the State of New York, with offices at 43 Exchange Place, New York City, Dr. Hans Goldschmidt, of Essen, being president, Mr. E. Stütz vice-president and general manager. While the company is specially interested in the introduction of the thermit process in this country, it intends to conduct business generally in connection with the Chemical & Tin Smelting Works of Th. Goldschmidt, Essen-Ruhr, Germany (founded 1847), and is prepared to handle all products dealt in by the large parent concern. On February 25 Mr. Stütz delivered a lecture on aluminothermics before the Boston Section of the American Chemical Society. The lecture was greatly appreciated, the attendance being over 900.

PERSONAL.

Prof. J. W. Richards, of Lehigh University, is now delivering a series of lectures at Columbia University on iron and steel metallurgy.

Dr. Max von Recklinghausen, who was instrumental in developing the Nernst lamp, and the Cooper-Hewitt lamp in this country, has left for Europe, to establish a Cooper-Hewitt lamp factory abroad.

DIGEST OF U. S. PATENTS

PRIOR TO JULY, 1902.

Compiled by Byrnes & Townsend,
Patent Lawyers,
National Union Building, Washington, D. C.

CHEMICALS.

683,000. September 17, 1901. Isaiah L. Roberts, New York City.

Manufactures aluminium hydrate from bauxite by pulverizing the bauxite and heating it in an aqueous solution of caustic alkali until most of the aluminium hydrate is dissolved out. The resulting sodium aluminate solution is filtered and electrolyzed in a cell having a diaphragm consisting of concentric baskets of rubber-covered wire, with their opposing faces covered with cloth and the intermediate space filled in with a stiff paste of finely pulverized anthracite coal, and a 12 to 20 per cent solution of sodium hydrate. A platinum or glass-cemented carbon anode is placed in the diaphragm and the

outer iron vessel constitutes the cathode. The cathode compartment is filled with a weak solution of caustic soda, and the anode compartment with the electrolyte. The aluminium hydrate is deposited on the anode and thence falls to the bottom of the anode compartment. The resulting caustic soda is removed from the cathode compartment and used to dissolve more bauxite and the spent solution from the anode compartment is removed to the cathode compartment.

690,048. December 31, 1901. Lewis Cheesman, Sr., Alxandria, Va.

Treats natural phosphates, e. g., apatites, corprolites, etc., by crushing the rock to powder, mixing with water and nitre cake, and passing electricity through the mixture, using electrodes of platinum. The product is "a residuum of monobasic phosphate, di-basic phosphate, and other compounds." May siphon off the liquid from the cell, evaporate and "add to the solution sufficient sulphuric or nitric acid to render the same slightly acid. In this way the salts soluble in water remain water-soluble."

692,688. February 4, 1902. Maurice Meslans, Paris, France.

An apparatus for producing fluorin by electrolyzing anhydrous hydrofluoric acid containing 25 per cent of fluohydrate or fluorid of potassium. One or more anode compartments consisting of a box of copper having its walls coated with an insulating and inert layer of copper fluorid. The side of the box below the electrolyte consist of superposed, spaced strips of V-section, which maintain the gases separate. A fluorin discharge pipe and a second pipe to assist in expelling the gas open into each anode compartment. A pipe for discharging hydrogen leads from the cathode compartment. The joints in the apparatus contain rubber gaskets. To cool the electrodes, the whole apparatus is immersed in a refrigerating-tank, and a refrigerating liquid may be carried through the hollow anodes by pipe connections. The gas-discharge pipes may comprise coils immersed in a refrigerating liquid, thereby condensing any hydrochloric and returning it to the cell.

695,573. May 20, 1902. Max Buchner, Mannheim, Germany.

Converts wood into dextrine, glucose and alcohol. Reduces the wood to shavings, sawdust or pulp and subjects to the action of a boiling solution of calcium hypochloric and hydrate for an hour or two, then slightly acidifies with sulphuric acid. Again treats at a temperature of 100° C., with water containing 2 per cent of sulphuric and phosphoric acids, until the liquid contains dextrine; then heats in a digester to 150° to 160° C. Neutralizes by introducing calcium or barium carbonate and bleaches the resulting dextroglucose by water charged with sulphurous acid and zinc. To produce alcohol, omits bleaching and passes electricity through the mass in the digester, adding to the cellulose wort, or a little wort containing albuminoid substances such as beet-root or grain. May produce the electric current by placing a zinc-copper couple in the digester. In the apparatus shown the metal digester and a central copper rod projecting from its bottom serve as the cathode, the anodes being a circular row of carbon rods.

700,670. May 20, 1902. Max Buchner, Mannheim, Germany.

Reduces nitro compounds to amins by dissolving or suspending in a suitable bath and electrolyzing with a tin cathode or an indifferent cathode, e. g., of platinum, lead, carbon or nickel, adding stannous chloride to the cathode electrolyte. The tin continuously dissolves from the cathode, effecting the reduction, but is simultaneously redeposited by the current.

Example 1.—Reduction of Nitrobenzene to Anilin.

(a) With a tin cathode.—An electrolytic cell is divided into an anode and a cathode space by means of a suitable and convenient diaphragm. Into the former is poured sulphuric acid of 30 per cent strength, and an anode of indifferent material is arranged therein. The cathode space is preferably provided with a stirring apparatus, and a cooling envelop of any suitable description. Into this cathode-space is introduced a solution of one hundred and fifty parts, by volume, of alcohol, fifty parts, by volume, of fuming hydrochloric acid, and twenty-five parts, by volume, of nitrobenzene or a mixture of twenty-five parts, by volume, of nitrobenzene, with fifty parts, by volume, of fuming hydrochloric acid and fifty parts, by volume, of water. The cathode is an electrode made of tin. When all the parts and materials are in place, the reduction is effected by introducing an electric current of a density preferably of eighteen hundred amperes per square meter for a bath potential of 6.5 volts. When the reaction process is completed, hydrogen begins to escape regularly, and thereby the end of the operation is indicated. The current is now cut off, the colorless cathode-bath is separated from the tin sponge or flakes suspended therein by filtration, and the filtrate is evaporate. The residue is anilin chloride in the form of a colorless crystalline mass, from which the anilin may be isolated by known methods.

(b) With an indifferent cathode in the presence of a tin salt.—An indifferent cathode, consisting, for example, of a net of nickel wire, is arranged in the cathode-space and two parts, by weight, of stannous chloride are added to the cathode-bath, which consists of a mixture of twelve parts, by weight, of nitrobenzene, with seventy-five parts, by volume, of fuming hydrochloric acid and fifty parts, by volume, of water. On introducing into this electrolyte a current having a density of 1000 amperes per square meter for a bath potential of 8.5 volts, metallic tin, is first deposited on the nickel cathode. As soon as the evolution of hydrogen begins, thereby indicating the complete reduction of the nitrobenzene in the cathode bath, further quantities of nitrobenzene, together with the amount of hydrochloric acid necessary to form anilin chloride from the same, may be added to the bath, such further addition being repeated and contained until the solution is enriched with anilin chloride to such an extent that it will directly solidify to a crystalline mass on cooling.

Example 2.—Reduction of Paranitrotoluene to Paratoluidin.

The cathode-space is charged with a mixture of twenty parts, by weight, of paranitrotoluol, one hunderd parts, by volume, of concentrated alcohol (fine spirts), and ten parts, by volume, of fuming hydrochloric acid.

Example 3.—Reduction of Meta-Dinitrobenzene to Meta-Phenylendiamin.

The cathode-space is charged with a mixture of twenty parts, by weight, of meta-dinitrobenzene, two hundred and fifty parts, by volume, of rectified alcohol (fine spirits), and one hundred and fifty parts, by volume of fuming hydrochloric acid.

Example 4.—Reduction of Alpha-Nitronaphthalin to Alpha-Naphthylamin.

The cathode bath consists of a mixture of twenty parts, by weight, of alpha-nitronaphthalin two hundred and seventy parts, by volume, of rectified alcohol (fine spirits), and fifty parts, by volume, of fuming hydrochloric acid.

Example 5.—Reduction of Phenylnitromethane to Benzylamin.

The cathode-space is charged with a mixture of five parts, by weight, of phenylnitromethane, one hundred parts, by volume, of rectified alcohol (fine spirits), and two hundred parts, by volume of fuming hydrochloric acid.

700,672. May 20, 1902. Max Buchner, Manheim, Germany.

Similar to 700,670, but employs copper instead of tin as a reducing agent.

Example 1.—Reduction of Nitrobenzene to Anilin Chloride.

Anode solution, 10 per cent sulphuric acid. Cathode, platinum. Cathode solution: Fuming sulphuric acid, nve hundred parts; water, five hundred parts; nitrobenzene, one hundred and twenty-three parts; cuprous chloride, thirty parts. The nitrobenzene is maintained in suspension by a revolving stirrer, and is replaced as consumed. Current, 1900 amperes per square meter, making cooling desirable. Reduction complete when hydrogen appears.

Example 2.—Same as first, but substitutes 20 grams of finely divided copper for the cuprous chloride.